6.0 SOURCE CHARACTERIZATION - SOILS

From the over 800 soil samples taken and used in the RFI, approximately 40 constituents including TICs were detected above their respective delineation criteria[1]. Many of the chemicals were detected infrequently. The most commonly detected chemicals that were also detected above their respective delineation criteria include benzene, PAHs (primarily benzo(a)pyrene), and metals (lead, TOL, and arsenic).

The main sources of environmental impact at the Refinery are likely to be associated with:

- The historical practice of filling low areas with potentially impacted dredge spoils, fill and Refinery wastes (for example, demolition debris and tank bottom deposits) to facilitate Refinery expansion;
- Residuals in waste management units such as oil/water separators, TEL burial sites, wastewater treatment system components and other units including the OWSS; and
- Accidental spills and leaks from operational units and pipelines.

In general, the vertical and horizontal delineation of these exceedances on an area or site-wide basis has been achieved. The Facility-related chemical impacts are generally contained within the fill layer. The native peat/clay layer that underlies much of the Refinery is not impacted, except for some areas heavily impacted by LNAPL, where potential petroleum impacts have been identified in the upper peat layer.

Although arsenic has been detected in many of the soil samples from the Refinery, approximately 85% of the samples contained concentrations of arsenic at concentrations less than that considered to be background in New Jersey soils, as represented by the NJDEP SCC for both residential and industrial land use and various New Jersey soils (Sanders, 2003). In addition to naturally-occurring background, anthropogenic off-site activities (e.g., smelting and refining) may account for some of the higher arsenic soil concentrations (the maximum arsenic soil concentration was 117 mg/kg). Alternatively, these higher concentrations may represent background concentrations as well since elevated arsenic soil concentrations have been found to be naturally occurring in New Jersey (e.g. marine clay), where total arsenic levels have been reported to range from 13 to 131 mg/kg (Sanders, 2003). Therefore, arsenic is not considered a Facility related-chemical.

Site-wide exceedances of soil delineation criteria associated with PAHs, particularly benzo(a)pyrene, while constituents of petroleum, are widespread and inconsistent with a pattern of spills and releases (i.e., not attributable to known waste management units, but

[1]The soil delineation criteria were identified as the most stringent of the applicable direct contact or impact to groundwater criteria and priority was given to the NJDEP SCC.

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more likely associated with the historical practice of filling low areas with potentially impacted dredge spoils, fill and Refinery materials to facilitate Refinery expansion). In other areas, these exceedances are part of the LNAPL areas and are collocated with VOC exceedances, predominantly benzene, representing the lighter end of the petroleum distillate range.

TOL has been detected in soils at the confirmed TEL burial sites, and in many cases has degraded to inorganic lead. Based on the RFI data and consistent with the literature, most of the lead associated with TEL has been retained, likely as stable solid phase compounds, precipitates or complexes with organic matter. These forms of lead are quite insoluble and are unlikely to leach into groundwater unless acidic conditions are present.

~~This~~ The remainder of this section presents an overview of potential sources of contamination (e.g., the types of SWMUs and AOCs at the Chevron Perth Amboy Refinery) (Section 6.1), the approach and findings of the 1st ~~1~~ and Full RFI soil sampling investigations (Section 6.2) and the nature and extent of soil contamination for each of the three main areas of the site (North Field/Main Yard, Central Yard and East Yard) (Section 6.3). A brief discussion of the fate and transport mechanisms for the primary COCs is ~~also~~ provided in Section 6.4. A summary is presented in Section 6.5.

6.1 Identification of Potential Sources

Identifying potential sources of contamination is essential to understanding potential exposure pathways ~~and to develop a technically sound sampling strategy~~. As discussed in detail in Section 2 (Facility Background and Land Use), t~~T~~he Refinery has been dedicated to asphalt production and refining petroleum hydrocarbons since the late 1800's. Thus, a degree of industrial impact is expected to be present. ~~In particular, the main sources of environmental impact at the Refinery are likely to be associated with:~~

- ~~The historical practice of filling low areas with potentially impacted dredge spoils and fill and Refinery wastes (for example, demolition debris, sludges and tank bottom deposits) to facilitate Refinery expansion;~~
- ~~Residuals in waste management units such as OWSs, TEL burial sites, wastewater treatment system components and other units including the OWSS; and~~
- ~~Accidental spills and leaks from operational units and pipelines.~~

In general, the RFI is expected to identify releases that resulted from accepted practices employed before the advent of modern waste management procedures and current regulations.

Table 2-2 includes a list of SWMUs and AOCs that have been identified in the North Field/Main Yard, Central Yard and East Yard portions of the Refinery[2]. ~~The western~~

[2]The western portion of the Refinery, which includes the ATF and the West Yard, is not included in this RFI, because it is the subject of on-going remedial activities as part of a City of Perth Amboy

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~~portion of the Refinery, which includes the ATF and the West Yard, is not included in this RFI, because it is the subject of on-going remedial activities as part of a City of Perth Amboy redevelopment project.~~ SWMAs consist of SWMUs and AOCs that either overlap or are located in close proximity to each other. Figure 2-2 shows the location of each SWMU and AOC.

The following general categories of SWMUs and AOCs have been identified at the Refinery:

- TEL burial sites and weathering areas;
- Current process water/stormwater treatment system (OWSS and ETP);

redevelopment project. As discussed in Section 2, the NFE is an isolated portion of Refinery property that was used by companies other than Chevron, and is also being evaluated separately from the RFI.

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- Historical process water treatment units (separators, ponds, sludge drying areas);
- Storage/disposal areas and miscellaneous units;
- Potential accidental pipeline releases;
- Potential accidental tank releases;
- Petroleum impacted fill; and
- LNAPL areas.

6.1.1 TEL Burial Sites and Weathering Areas (SWMUs 5 through 27 and SWMU 53)

TEL was used at the Refinery as a gasoline additive to increase octane rating. While being stored in ASTs, there was the potential for the TEL to settle out of solution and collect on the tank bottom, along with other sludges. These deposits would periodically be removed from the tank bottoms and exposed to light, so that any TEL present would photolytically decay. The deposits would then be spread or buried in the soils around the Refinery, typically within the basin or near the tank being cleaned. Initially, in accordance with standard industrial practices of the time, the TEL-bearing sludge was buried in pits and covered with excavated soil. Later, these leaded tank sludges were landfarmed (weathered) rather than buried.

The information available about the TEL burial sites and weathering areas was based primarily on a review of a plot plan marking locations of burial sites and proposed leaded sludge weathering sites ~~(Figure 2-1)~~. Refinery personnel also provided some operational information. The burial of TEL began prior to 1963. Use of burial and weathering sites reportedly ceased in 1975 when leaded gasoline usage began to be phased out. Chevron's remaining TEL was subsequently transported and disposed off site.

The TEL burial sites were usually directly adjacent to the tank from which the TEL-bearing sludge was removed. Typically, the burial site pit dimensions were approximately 20 feet by 20 feet. One larger pit is marked with dimensions of 10 feet wide by 45 feet long by 10 feet deep, with five feet of cover. This burial site is the only one where the total depth and depth of cover was specified. It is not known if this was typical for other TEL disposal pits.

TEL weathering areas reportedly supplanted TEL burials in the early to mid-1960's, after it was discovered that organic lead rapidly degrades to its less toxic inorganic form under normal atmospheric conditions. The TEL weathering areas were reportedly roped off and the TEL-bearing tank bottom sludges were tilled into the soil. The plot plan marking locations of TEL sites shows four added proposed sludge weathering sites (the date of this addition is August 1963). As reported in the DOCC (ESE, 1994), discussions with Refinery personnel and roping with danger signs confirmed the presence of the two weathering areas in the North Field. However, the use of the two possible weathering

sites in the East Yard could not be confirmed, and subsequent construction of the EYB may have disturbed these sites, if in fact they existed.

6.1.2 Current Process Water/Stormwater Treatment System

The combined process water and stormwater treatment system at the Refinery includes the OWSS (AOC 16) and the ETP (SWMU 31). The OWSS collects stormwater and process water and routes it to the ETP. The ETP, which has been in operation since 1977, treats process water (wastewater generated from the process areas) and stormwater and recovers recyclable material. The effluent from the ETP is discharged to Woodbridge Creek under an NJPDES-DSW permit. There have been no documented releases from this SWMU, and no action is required per Module III A.3.c.ix of the HSWA permit.

Oily Water Sewer System (AOC 16)

The OWSS (AOC 16) consists of approximately eleven (11) miles of underground piping that connects the tank basins and process areas to the ETP. The OWSS in the North Field/Main Yard and Central Yard flow to the ETP via gravity. The process water and stormwater from the East Yard are pumped to the ETP.

The OWSS was constructed prior to 1950. Chevron has added new sections to the OWSS as new tank basins and process areas were constructed. A 1950 Refinery Drawing (BA 925-4664-9) indicated that the OWSS is primarily constructed of salt-glazed vitrified clay. The diameter of the OWSS pipe ranges from one foot to five feet in diameter, and it was placed roughly six to eight feet below grade. In the southern and western parts of the Refinery, the OWSS is above the water table. In the northern and eastern parts of the Refinery, the OWSS is below the water table.

The OWSS receives process water from the Crude Unit, as well as the following:

- Desalter water and cooling tower blowdown;
- Stormwater runoff from process areas;
- Stormwater runoff from tank basins;
- Drawdown water from ASTs; and
- Steam condensate.

The entrained hydrocarbons in the water are recovered at the ETP and recycled into the process units, while the water receives further treatment within the ETP prior to discharge into Woodbridge Creek under an NJPDES permit.

The diked basins around the ASTs have catch basins with manually controlled valves to control the flow of stormwater from the tank basins. During storm events, the flow of stormwater into the OWSS is controlled by closing the catch basin valves.

Prior to construction of the ETP in 1976, the OWSS discharged the water to several oil/water separators, where oil was recovered and some solids were allowed to drop out of suspension. The water was then discharged to either Woodbridge Creek or the Arthur Kill, depending on the location of the separator.

6.1.3 Historical Process Water Treatment Units (Separators, Ponds and Mudflats)

Separators (SWMUs 35 and 36)

Two former oil/water separators have been designated as SWMUs. The No. 4 Separator (SWMU 35) was located in the North Field west of the ETP. The oil/water separator near the EYB (SWMU 36) was located in the eastern portion of the East Yard (Figure 2-2). The exact operation of these former separators has not been fully documented. In general, oily stormwater and process water would flow through the oil/water separators for a designated residence time, allowing the water and hydrocarbons to separate. The oil would then be collected by skimmers and the water would flow under a weir prior to discharge to Woodbridge Creek and the Arthur Kill. SWMUs 35 and 36 operated from approximately 1950 to 1977.

Ponds/Mudflats (SWMUs 1, 2, 3, 38, 39, 40, 43, 44 and 45)

Several surface water impoundments/ponds have been identified based on historic aerial photographs and a review of Refinery records. Three of these historic ponds/holding basins, including the NFB (SWMU 1) and the Surge Pond (SWMU 2) located in the North Field, and the EYB (SWMU 3) located in the East Yard, are being closed in accordance with the approved NJPDES-DGW Permit. The NFB and EYB were used primarily as stormwater retention basins, while the Surge Pond was used primarily for on-site storage of Refinery wastes. As these units are closed or being closed under the State's NJPDES-DGW Permit, no further discussion is warranted.

The remaining SWMUs (38, 39, 40, 43, 44 and 45) are potential units that have been classified as ponds or mudflats. These SWMUs have been identified in historical aerial photographs and may have been used to manage oily stormwater and process water. Brief descriptions of these units are provided below:

- **SWMU 38:** The North Field Slop Pond is located in the North Field. This unit is part of SWMA 2.
- **SWMU 39:** The Unnamed North Field Pond is located in the North Field and is now part of SWMA 1.
- **SWMU 40:** Old Pond is a former surface impoundment in the North Field that was used in conjunction with an oil/water separator.
- **SWMU 43:** The Mudflats is a former below grade surface impoundment that was in operation between 1955 and 1975. It is now part of SWMA 3.
- **SWMU 44:** The Unnamed Main Yard Pond is a former historic earthen impoundment located in the Main Yard under the present location of the Utility Plant.

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- **SWMU 45:** The "Kidney Pond" was a below grade impoundment that was located next to the oil/water separator near the EYB (SWMU 36). The unit was removed/closed prior to the construction of the EYB (SWMU 3) in 1977. In accordance with the HWSA Permit, no further action is required at SWMU 45.

~~These SWMUs have been identified in historical aerial photographs and may have been used to manage oily stormwater and process water. In accordance with the HWSA Permit, no further action is required at SWMU 45.~~

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6.1.4 Storage/Disposal Areas and Miscellaneous Units (SWMUs 28, 29, 30, 32, 34, 51 and 53)

Seven of the SWMUs have been classified as storage areas or disposal areas. These areas have been used for the storage and/or disposal of miscellaneous Refinery wastes. While there is occasional stained concrete at some of the units, there is no direct evidence to indicate the location, content or extent of any releases. Potential releases from these SWMUs, if any, would most likely affect surface and subsurface soils, and no unit in this category is located immediately adjacent to Refinery boundaries or offsite surface water bodies. Therefore, the release identification and risk assessment activities at these SWMUs will focus on the soils.

Brief descriptions of the seven storage and disposal units are provided below:

- **SWMU 28:** The reactor burial is a reactor vessel used for the production of phthalic anhydride that was destroyed by an explosion and fire in the 1960's and buried in the northwest portion of the North Field/Main Yard. The Reactor contains a vanadium pentoxide catalyst that is contained in an inert carborundum matrix. The reactor is buried under approximately four feet of soil. SWMU 28 is included in SWMA 2.
- **SWMU 29:** The Fines Transfer Area in the northwest portion of the North Field was used to transfer spent Houdry cat cracker catalyst fines containing nickel and vanadium into dumpsters prior to 1982. Fines were piled to the east of the ramp and dumpsters were placed to the west of the ramp. SWMU 29 is included in SWMA 1.
- **SWMU 30:** The Short-Term Storage Area in the northwest portion of the North Field/Main Yard is a fenced area with locking gates and a gravel base. SWMU 30 is used for the temporary storage (less than 90 days) of hazardous and potentially hazardous wastes prior to removal. Miscellaneous wastes are stored in 55-gallon drums, asbestos-containing materials are stored in bags placed in closed trailers and oily rags and other oil wastes are stored in rolloffs. SWMU 30 is part of SWMA 2.
- **SWMU 32:** The PCB Waste Storage Area is located within a warehouse located in the East Yard. There have been no documented releases from SWMU 32, and no further action is required according to the HSWA Permit.
- **SWMU 34:** The dumpster and drainage area located in the southern portion of the Central Yard previously contained a concrete loading pad for construction debris and was used as a staging area for scrap metal, empty drums, and dumpsters prior to 1983 to approximately 1993. The dumpsters contained general non-hazardous refuse (empty drums of petroleum products, scrap metal, asphalt spill material and SRU catalyst[3]).
- **SWMU 51:** The Oily Soil Pad is an asphalt pad located in the Main Yard that was constructed in 1990. This unit is used for temporary staging of non-hazardous soil excavated during on-site construction and demolition activities or as the result of on-site spill responses. There have been no documented releases from this unit, and no further action is required according to the HSWA Permit.
- **SWMU 53:** The northwest corner of Tank Basin 312, located in the North Field, was used as a collection site for fluids from the FFTG, where small fires typically fueled with naphtha were set for training activities. The FFTG drainage system was designed to discharge fluids into the basin via a below-grade drain that is connected to the ETP for further treatment.

[3]An odor complaint was reported to the Middlesex County Department of Health (MCDH) on April 5, 1983. An MCDH inspector traced the odor to the dumpster area, where the offending substance was later determined to be catalyst from one of the SRUs, which had been placed in one of the dumpsters.

6.1.5 Potential Pipeline Releases (SWMU 42, and AOCs 15, 19, 26, 27, 30 and 31)

One SWMU and six AOCs represent potential releases from pipelines or associated manifolds. These pipeways have been used for handling a variety of oil products, including crude oil, asphalt, No. 6 fuel oil, diesel fuel, No. 2 fuel oil, gas oil and recovered oil.

The East Yard Crude Slab (SWMU 42) is a pipe trench containing numerous pipes, manifolds, pumps and valves positioned over a concrete containment slab. The pipeways have been used for handling "black oil products", which include crude oil, various grades of asphalt and heavy oil, such as No. 6 fuel oil and bunker fuel. In 1998, a 12-inch pipeline adjacent to the slab failed, and approximately 14.5 tons of released material were excavated and disposed off-site. After identifying an LNAPL area at SWMU 42, Chevron initiated IRMs, which are currently ongoing.

Six AOCs include areas of stained soils or releases associated with pipelines in the North Field (AOC 15), Main Yard (AOC 19), East Yard (AOCs 26, 27 and 31) and Central Yard (AOC 30).

6.1.6 Potential Tank Releases (AOCs 1 - 3, 5, 17, 18, 22, 23, 28 and 32 - 35)

Throughout the operational history of the Refinery, the tank farms have stored various refined and unrefined products. The tank farms consist of individual tanks, or groups of tanks, surrounded by berms constructed of soil. Apparent discharges within the bermed areas of several of the tanks were observed in historical aerial photographs. Some tanks in the tank farms have been decommissioned and dismantled; however, many are still in use. The potentially affected media in the tank farms are surface soil, subsurface soil and groundwater. Potential releases from tanks are associated with Tanks 1 through 4, 20, 314 and 315 (AOCs 1, 18, 2, 3, 17, 33 and 34, respectively) in the Main Yard; Tank 327 (AOC 23) in the North Field; Tank 16 (AOC 32) in the Central Yard; Tanks 718 and 719 at the Asphalt Plant (AOC 28); and Tank 771 (AOC 35) in the East Yard.

Two of the potential tank releases consist of stained soil or groundwater contamination that was observed during the excavation and removal of USTs in the North Field (AOC 5) and Central Yard (AOC 22).

6.1.7 Petroleum-Impacted Fill Material (AOCs 6A, 6B, 6C, 7, 8, 9A, 9B, 10, 13, 14, 21, 24, 25 and 29)

Stained soils, petroleum materials or other evidence of potential contamination have been identified at various locations throughout the Refinery. In some cases, the observed contamination is not immediately attributable to known waste management units. Other areas, such as AOC 6B and ~~and~~ AOC 14, ~~,~~ are part of the LNAPL areas discussed below. These areas may represent zones of historical fill where soil containing petroleum

constituents may have been used as fill during construction activities. The origin ~~and extent~~ of the pre-existing contamination in the stained soil used as fill ~~are~~ is unknown.

6.1.8 LNAPL Areas

LNAPL at the Refinery consists of liquid petroleum hydrocarbons that are visibly distinguishable from water as a separate fluid. A total of 17 LNAPL areas have been identified in the North Field/Main Yard, East Yard and Central Yard. Most of these areas were discovered during the 1st-Phase RFI, ~~or during~~ the 1st ~~or 2nd~~-Phase OWSS investigation or the Phase II ~~Phase~~ OWSS investigation. The LNAPL areas have been identified based on the presence of LNAPL inside temporary piezometers~~. LNAPL has also been observed in a number of soil borings throughout the different yards.~~. Detailed discussions of LNAPL areas are provided in Section 7.

6.2 RFI Soils Characterization Approach

As discussed in Module III of the HSWA permit, the purpose of the 1st-Phase RFI was to conduct confirmatory sampling to identify if releases have occurred from the SWMUs and AOCs[4]. In accordance with the HSWA requirements for a full RFI Investigation as set forth in Module III (Appendix A, Part VI, Task IV, Subparts B and C), SWMU/AOC-specific work plans were developed and implemented to provide additional data for source and contaminant characterization and risk ~~evaluation~~characterization. ~~The additional delineation of LNAPL areas is included in Section 7.~~ The discussions for each SWMU and AOC, including a brief description of ~~the SWMU or AOC~~each area and a summary of specific boring and sampling results, are provided in Appendix A[5].

Multiple investigations of the Refinery have provided a large database of analytical results. The database includes analyses from potentially affected media. Most of the 1st-Phase RFI, and 1st-Phase and Phase II OWSS investigations samples were analyzed for the chemicals on the RCRA Skinner's List, which was designed to provide data on the most prevalent types of waste found at petroleum refineries. The 1st-Phase ~~I~~RFI soil samples from potential TEL sites were also analyzed for TEL. In addition, ten percent of the samples collected during the Phase ~~2~~ II OWSS Investigation were ~~also~~ analyzed for TCL/TAL compounds ~~on the TCL/TAL~~, which is more extensive than the Skinner's List.

During the Full RFI, samples collected during t~~T~~he first iteration sampling round ~~of samples was~~ were analyzed for TCL/TAL compounds. Samples from TEL sites were also analyzed for TOL[6]. During t~~T~~he second iteration sampling round, ~~of~~ soil samples ~~collected during the full RFI~~ were analyzed for a subset of compounds, depending on the

[4]The OWSS (AOC 16) has been the subject of two major investigations. These include: the *1st-Phase Oily Water Sewer System Investigation Report RCRA Corrective Action Module #3* (Chevron, September 1997) and the *Phase II OWSS Investigation* Report (Chevron, March 2002).

[5]The additional delineation of LNAPL areas is included in Section 7.

[6]TEL and TOL were both analyzed using the California LUFT method and are essentially the same analysis; however, it is more appropriate to report the analysis as TOL, as the method does not speciate for TEL.

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specific COCs that were detected above applicable delineation criteria at a given SWMU or AOC.

6.2.1 1st- ~~1st~~ –Phase RFI, ~~Investigation and 1st- and 2nd~~ –1st-Phase OWSS and Phase II OWSS Investigations

The primary objective of the 1st-~~1st~~ Phase RFI was to confirm whether a release had occurred. Many of the SWMUs and AOCs were identified based on historical aerial photographs, or in the case of TEL sites, because they were depicted on the "Proposed TEL Burial Map". However, some of these areas were never actually used for TEL burials or other types of waste management. Therefore, if ~~an~~ a 1st-Phase action level was exceeded at a given location, it was assumed that a release had occurred, no further sampling was conducted, and the area would be included in the full RFI. However, if action levels were not exceeded, sampling continued at a given SWMU in accordance with the 1st-Phase sampling strategy~~,~~ until either a release was identified or sampling confirmed that the area had never been used for TEL burial or other waste management activities. As a result, sampling activity varied among areas.

A screening process was used to identify the chemicals that were detected during historical sampling investigations at frequencies and concentrations that warranted further investigation during the RFI. This screening process included a comparison of historical data to 1st-Phase RFI action levels.

For the 1st-Phase RFI for soils, the action levels for soil were derived by selecting the lowest standard from applicable NJDEP and RCRA Subpart S soil criteria. ~~, which included:~~

- ~~NJDEP Non-Residential Direct Contact Soil Cleanup Criteria;~~
- ~~NJDEP Impact to Groundwater Soil Cleanup Criteria; and~~
- ~~RCRA Subpart S Action Levels.~~

For the 1st-Phase RFI for groundwater, the action levels were derived from NJDEP groundwater criteria for VOCs, SVOCs and metals, and site-specific background groundwater concentrations for a limited group of metals that were detected in upgradient background wells. ~~The action levels were selected by choosing the highest of the following concentrations for a given analyte: NJDEP Class IIA GWQC, the NJDEP suggested PQL for the analyte and the actual PQL of the analytical laboratory.~~

The sampling strategy during the Phase II OWSS was modified to target potential groundwater impacts. One groundwater sample was collected at each of the proposed sampling points, and soil samples were to be collected from the vadose zone if evidence of environmental impacts were observed.

Over 170 soil samples were collected from the three yards during the 1st-Phase Soils Investigation. More than 90 additional samples were collected during the ~~1st- and 2nd~~ 1st-Phase and Phase II OWSS Investigations.

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6.2.2 Full RFI Soils Investigation

The proposed sampling strategy during the full RFI for each SWMA, SWMU and AOC was an iterative process designed to provide additional data for the following purposes:

- Further define the lateral and vertical extent of the potentially impacted soils;
- Characterize the potentially impacted soils; and
- Provide adequate data for risk characterization.

The number of samples collected at each SWMU and AOC during the full RFI was dependent on the number of samples that had been previously collected as well as to address gaps in delineation per the RFI Workplan. In most cases, one or two additional borings were sufficient to better define the lateral extent of the potentially-impacted soils. This was often the case at SWMUs where one of the outermost samples had an action level exceedance.

At each sampling location, continuous borings were completed to the water table or until native material was encountered, in order to further delineate the vertical extent of the potentially-impacted soils. A portion of the soil sample from every two-foot depth interval was screened for volatile organic vapors. Samples for VOC analysis were collected as soon as the split spoon sample was opened to prevent potential loss of VOCs. During the first iteration, three samples from each boring were sent for laboratory analyses as follows:

- A surficial soil sample was collected from approximately zero to ~~2~~ two feet bgs or immediately below pavement. Samples for VOC analysis were collected in accordance with the NJDEP TRSR requirements, as defined in 7:26E-3.6(1)4.
- A second sample was selected based on headspace screening as well as visual observations. The sample that exhibited the highest headspace reading and/or the most signs of contamination was selected for analysis. If none of the sampling intervals showed evidence of visual contamination or elevated headspace readings, the soil sample from the interval just above the water table was selected for analysis.
- A third sample was collected in the native material ~~1~~ one to ~~2~~ two feet below the fill layer (e.g., peat, clay~~ or outwash~~, etc.), provided that there was no visual evidence of contamination or elevated headspace readings. If there was evidence of contamination in the uppermost portion of the native material, then the sample was collected from the interval approximately ~~1~~ one to ~~2~~ two feet below the last evidence of contamination.

All samples collected during the first iteration of the full RFI were analyzed for TCL VOCs and SVOCs and TAL metals, unless otherwise noted. Samples from TEL sites were also analyzed for TOL. ~~to confirm the findings of the 1st Phase sampling results.~~

A second iteration of sampling was conducted after the results from the first round of sampling were evaluated. The need for and placement of additional samples for delineation of SWMUs and AOCs was based on the results from the initial samples that had been proposed in the RFI Work Plan, coupled with previous analytical data in order to delineate and characterize potentially impacted soils. These data and additional proposed sampling locations were presented and discussed with the Agencies during three meetings that occurred during the autumn of 2002. Additional samples were collected and analyzed for a subset of the TCL/TAL list, depending on which COCs required additional delineation. Approximately 566 soil samples were collected during the Full RFI.

6.2.3 Full RFI Delineation Criteria

As discussed in detail in Section 4 and Appendix A, s~~S~~oil and groundwater delineation criteria were used to screen both the full RFI data and previous relevant data so that the need for further evaluation and delineation could be determined[7]. In the RFI Workplan, Chevron proposed a hierarchy for selecting soil and groundwater delineation criteria. Tables 4-7 and 4-8 ~~6-1~~ list~~s~~ the delineation criteria for soil and groundwater. ~~In general, NJDEP criteria are specified, with the following exceptions:~~

- ~~Figure 6-1 provides a generic flow chart for identification of soil delineation criteria, including the situation where NJDEP does not have criteria for a detected constituent, but an EPA resource has identified a criterion for soil;~~
  - ~~In cases where the delineation criteria is lower than analytical limits (such as TOL), the delineation criteria was based on the laboratory's reporting limit. In EPA's letter to Robert E. Mancini dated November 18, 2002, EPA and NJDEP agreed that the delineation criteria for TOL could be based on the Limit of Quantification (LOQ) of 2 milligrams per kilogram (mg/kg).~~
  - ~~In addition, in Chevron's letter to Anthony Cinque dated February 12, 2003, Chevron requested approval by NJDEP for use of criteria different from those available from NJDEP for beryllium, chrysene, thallium and zinc in soil, and ammonia in groundwater. The Alternate Remedial Criteria (ARC) for direct contact only, approved by NJDEP and EPA for this site in EPA's letter dated August 22, 2003 are: beryllium (RDCSCC 16 parts per million (ppm),~~

[7] In addition to listing the most conservative delineation criteria, applicable screening levels for unsaturated soils, saturated soils, on-site soils and soils at the property boundary are provided in Appendix A. For example, certain compounds may be less mobile and therefore less likely to migrate from soil to water. In this case, the direct contact delineation criteria would be more conservative than the impact to groundwater delineation criteria, so the direct contact delineation criteria would be used for both unsaturated and saturated soils. In other cases, impact to groundwater criterion may be more conservative than direct contact criterion because the compound would be more likely to migrate to groundwater, in which case the most conservative criterion would apply to unsaturated soils only.

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~~NRDCSCC 200 ppm), thallium (RDCSCC 5.5 ppm, NRDCSCC 72 ppm), and chrysene (RDCSCC 62 ppm, NRDCSCC 230 ppm). The requested ARC for zinc was not approved by NJDEP, and the alternate groundwater standard for ammonia is pending because groundwater ARCs are obtained through the Bureau of Groundwater Pollution Abatement (BGWPA).~~

~~In addition to listing the most conservative delineation criteria, applicable screening levels for unsaturated soils, saturated soils, on site soils and soils at the property boundary are listed on Table 6-1, unless the most conservative delineation criteria is applicable to all cases. For example, certain compounds may be less mobile and therefore less likely to migrate from soil to water. In this case, the direct contact delineation criteria would be more conservative than the impact to groundwater delineation criteria, so the direct contact delineation criteria would be used for both unsaturated and saturated soils.~~

6.3 Nature and Extent of COCs in Soils

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6.3.1 Site-Wide Overview

~~Approximately 565 soil samples were collected during the Full RFI.~~ Data from ~~these samples~~the 566 soil samples collected during the full RFI, in combination with the data from the ~~264~~ 268 samples that were collected as part of previous investigations (e.g., 1st-Phase Soils, 1st-Phase OWSS and ~~2nd~~-Phase II OWSS) were used to evaluate each SWMU and AOC (see Appendix A), as well as to evaluate the nature and extent of potential releases at each yard. Approximately 80% of the soil samples (e.g., 665 of 830 samples) were analyzed for either TCL VOCs or Skinner's List VOCs. An additional 9% of samples were analyzed for BTEX compounds. Approximately 83% of the samples were analyzed for either TCL SVOCs or Skinner's List VOCs, and 56% of the samples were analyzed for either Skinner's List metals or TAL metals. An additional 30% of the samples were analyzed for lead only. Approximately 39% of the samples were analyzed for either TEL or TOL.

~~and AOC (see Appendix A), as well as to evaluate the nature and extent of potential releases at each yard. Approximately 80% of the soil~~ **~~Table 6-1 Full RFI Soil and Groundwater Delineation Criteria~~**

~~CAS #~~	~~Compound Name~~	~~Site Specific Groundwater (µg/L)~~	~~Soil~~ ~~Most Conservative (mg/kg)~~	~~Unsaturated PB (mg/kg)~~	~~Saturated PB (mg/kg)~~	~~Unsaturated On-Site (mg/kg)~~	~~Saturated On-Site (mg/kg)~~
~~7429-90-5~~	~~Aluminum~~	~~200~~	~~76,000~~	~~76,000~~	~~76,000~~	~~100,000~~	~~100,000~~
~~7440-36-0~~	~~Antimony~~	~~20~~	~~14~~	~~14~~	~~14~~	~~340~~	~~340~~
~~7440-38-2~~	~~Arsenic~~	~~8~~	~~20~~	~~20~~	~~20~~	~~20~~	~~20~~
~~7440-39-3~~	~~Barium~~	~~2,000~~	~~700~~	~~700~~	~~700~~	~~47,000~~	~~47,000~~
~~7440-41-7~~	~~Beryllium~~	~~20~~	~~16~~	~~16~~	~~16~~	~~200~~	~~200~~
~~7440-43-9~~	~~Cadmium~~	~~4~~	~~39~~	~~39~~	~~39~~	~~100~~	~~100~~
~~7440-70-2~~	~~Calcium~~						
~~7440-47-3~~	~~Chromium~~	~~100~~	~~120,000~~	~~120,000~~	~~120,000~~	~~120,000~~	~~120,000~~
~~18540-29-9~~	~~Chromium (Hexavalent)~~	~~110~~	~~240~~	~~240~~	~~240~~	~~6,100~~	~~6,100~~
~~7440-48-4~~	~~Cobalt~~	~~100~~	~~900~~	~~900~~	~~900~~	~~1,900~~	~~1,900~~
~~7440-50-8~~	~~Copper~~	~~1,000~~	~~600~~	~~600~~	~~600~~	~~600~~	~~600~~
~~57-12-5~~	~~Cyanide~~	~~200~~	~~1,100~~	~~1,100~~	~~1,100~~	~~21,000~~	~~21,000~~

and AOC (see Appendix A), as well as to evaluate the nature and extent of potential releases at each yard. Approximately 80% of the soil **Table 6-1.Full RFI Soil and Groundwater Delineation Criteria**

CAS #	Compound Name	Site Specific Groundwater (µg/L)	Soil				
			Most Conservative (mg/kg)	Unsaturated PB (mg/kg)	Saturated PB (mg/kg)	Unsaturated On-Site (mg/kg)	Saturated On-Site (mg/kg)
7439-89-6	Iron	300	23,000	23,000	23,000	100,000	100,000
7439-92-1	Lead	10	400	400	400	600	600
7439-95-4	Magnesium						
7439-96-5	Manganese	50	1,800	1,800	1,800	19,000	19,000
7439-97-6	Mercury	2	14	14	14	270	270
7440-02-0	Nickel	100	250	250	250	2,400	2,400
7440-09-07	Potassium						
7782-49-2	Selenium	50	63	63	63	3,100	3,100
7440-22-4	Silver	30	110	110	110	4,100	4,100
7440-23-5	Sodium	50,000					
7440-28-0	Thallium	10	6	6	6	72	72
78-00-2	Tetraethyl Lead		2	2	2	2	2
N/A	Total Organic Lead		2	2	2	2	2
744-03-15	Tin		47,000	47,000	47,000	100,000	100,000
7440-62-2	Vanadium	2,600	370	370	370	7,100	7,100
7440-66-6	Zinc	5,000	1,500	1,500	1,500	1,500	1,500
71-43-2	Benzene	1	1	1	3	1	13
100-41-4	Ethylbenzene	700	100	100	1,000	100	1,000
108-88-3	Toluene	1,000	500	500	1,000	500	1,000
1330-20-7	Xylene	1,000	67	67	410	67	1,000
83-32-9	Acenaphthene	400	100	100	3,400	100	10,000
208-96-8	Acenaphthylene	100	10,000	10,000	10,000	10,000	10,000
120-12-7	Anthracene	2,000	100	100	10,000	100	10,000
56-55-3	Benzo(a)anthracene	0.2	0.9	1	1	4	4
50-32-8	Benzo(a)pyrene	0.2	0.66	1	1	1	1
205-99-2	Benzo(b)fluoranthene	10	0.9	1	1	4	4
191-24-2	Benzo(ghi)perylene	100	10000	10,000	10,000	10,000	10,000
207-08-9	Benzo(k)fluoranthene	1	0.9	1	1	4	4
218-01-9	Chrysene	5	62	62	62	230	230
53-70-3	Dibenzo(a,h)anthracene	0.5	0.66	1	1	1	1
206-44-0	Fluoranthene	300	100	100	2,300	100	10,000
86-73-7	Fluorene	300	100	100	2,300	100	10,000
193-39-5	Indeno(1,2,3-cd)pyrene	10	0.9	1	1	4	4
91-20-3	Naphthalene	300	100	100	230	100	4,200
90-12-0	Methyl naphthalene, 1-	100	10,000	10,000	10,000	10,000	10,000
91-57-6	Methyl naphthalene, 2-	100	10,000	10,000	10,000	10,000	10,000
85-01-8	Phenanthrene	100	10,000	10,000	10,000	10,000	10,000
129-00-0	Pyrene	200	100	100	1,700	100	10,000
64-19-7	Acetic acid	-	10,000	10,000	10,000	10,000	10,000
67-64-1	Acetone	700	100	100	1,000	100	1,000
98-86-2	Acetophenone	1000	0.00022	0.00022	1000	0.00022	1000
107-02-8	Acrolein	-	0.1	0.1	0.1	0.34	0.34
107-13-1	Acrylonitrile			1	1	1	5
309-00-2	Aldrin		0.04	0.04	0.04	0.17	0.17
N/A	Alkalinity (as $CaCO_3$)						
N/A	Alkalinity to pH 4.5						
319-84-6	alpha-BHC (alpha HCH)	0.02	0.005	0.005	0.1	0.005	0.5

and AOC (see Appendix A), as well as to evaluate the nature and extent of potential releases at each yard. Approximately 80% of the soil **Table 6-1.Full RFI Soil and Groundwater Delineation Criteria**

CAS #	Compound Name	Site Specific Groundwater (µg/L)	Soil				
			Most Conservative (mg/kg)	Unsaturated PB (mg/kg)	Saturated PB (mg/kg)	Unsaturated On-Site (mg/kg)	Saturated On-Site (mg/kg)
5103-71-9	alpha-Chlordane	5	10,000	10,000	10,000	10,000	10,000
7664-41-7	Ammonia	3,000	10,000	10,000	10,000	10,000	10,000
62-53-3	Aniline	6	85	85	85	300	300
84-65-1	Anthraquinone, 9,10-	100	10,000	10,000	10,000	10,000	10,000
53469-21-9	Aroclor 1242		0.22	0.22	0.74		
12672-29-6	Aroclor 1248		0.22	0.22	0.74		
11097-69-1	Aroclor 1254		0.22	0.22	0.74		
11096-82-5	Aroclor 1260		0.22	0.22	0.74		
1912-24-9	Atrazine	3	2.2	2.2	2.2	7.8	7,8
100-52-7	Benzaldehyde	100	6,100	6,100	6,100	10,000	10,000
N/A	Benzen-d5-amine	100	10,000	10,000	10,000	10,000	10,000
108-98-5	Benzenethiol (thiophenol)	100	1	1	1	20	20
65-85-0	Benzoic acid	30,000	10,000	10,000	10,000	10,000	10,000
319-85-7	beta-BHC (beta-HCH)	0.2	0.4	0.4	0.4	2	2
N/A	Bicarbonate (as $CaCO_3$)						
92-52-4	Biphenyl (1,1-biphenyl)	400	350	350	350	350	350
111-91-1	Bis(2-cloroethoxy)methane	100	10,000	10,000	10,000	10,000	10,000
111-44-4	Bis(2-chloroethyl)ether	10	0.66	0.66	0.66	3	3
117-81-7	Bis(2-ethylhexyl)phthalate	30	49	49	49	100	210
80-05-7	Bisphenol A	100	3,100	3,100	3,100	10,000	10,000
314-40-9	Bromacil (pesticide)	5	10,000	10,000	10,000	10,000	10,000
108-86-1	Bromobenzene		28	28	28	92	92
75-27-4	Bromodichloromethane (Dichlorobromomethane)	1	1	1	11	1	46
460-00-4	Bromofluorobenzene, 4-		1,000	1,000	1,000	1,000	1,000
75-25-2	Bromoform	4	1	1	86	1	370
74-83-9	Bromomethane	10	1	1	79	1	1,000
101-55-3	Bromophenyl-phenylether, 4-	100	1,000	1,000	1,000	1,000	1,000
106-97-3	Butane	100	1,000	1,000	1,000	1,000	1,000
99-40-58	Butane, 2-methoxy-2-methyl	100	1,000	1,000	1,000	1,000	1,000
85-68-7	Butyl benzyl phthalate	100	100	100	1,100	100	10,000
123-05-5	Butyl stearate			10,000	10,000	10,000	10,000
104-51-8	Butylbenzene, n-	100	240	240	240	240	240
135-98-8	Butylbenzene, sec-	100	220	220	220	220	220
98-06-6	Butylbenzene, tert-	100	390	390	390	390	390
N/A	C11-C14		10,000	10,000	10,000	10,000	10,000
N/A	C15-C28		10,000	10,000	10,000	10,000	10,000
N/A	C29-C40		10,000	10,000	10,000	10,000	10,000
N/A	C6-C10	100	10,000	10,000	10,000	10,000	10,000
N/A	<C6		10,000	10,000	10,000	10,000	10,000
105-60-2	Caprolactam	100	10,000	10,000	10,000	10,000	10,000
86-74-8	Carbazole	5	0.6	0.6	24	0.6	96
624-64-6	Carbon Dioxide						
75-15-0	Carbon disulfide	800	32	32	1,000	32	1,000
N/A	Carbonate (as $CaCO_3$)						
56-23-5	Carbon Tetrachloride	2	1	1	2	1	4
5103-74-2	Chlordane, gamma			10,000	10,000	10,000	10,000

and AOC (see Appendix A), as well as to evaluate the nature and extent of potential releases at each yard. Approximately 80% of the soil **Table 6-1.Full RFI Soil and Groundwater Delineation Criteria**

CAS #	Compound Name	Site Specific Groundwater (µg/L)	Soil				
			Most Conservative (mg/kg)	Unsaturated PB (mg/kg)	Saturated PB (mg/kg)	Unsaturated On-Site (mg/kg)	Saturated On-Site (mg/kg)
16887-00-6	Chloride	250,000					
106-47-8	Chloroaniline, 4- (p-chloroaniline)	30	230	230	230	4,200	4,200
108-90-7	Chlorobenzene	4	1	1	37	1	680
74-97-5	Chlorobromomethane		10,000	10,000	10,000	10,000	10,000
75-00-3	Chloroethane	100	3	3	3	7	7
67-66-3	Chloroform	6	1	1	19	1	28
593-71-5	Chloroiodomethane	100	1,000	1,000	1,000	1,000	1,000
59-50-7	Chloro-m-cresol, p- (4-chloro-3-methyl phenol)	100	100	100	10,000	100	10,000
75-87-3	Chloromethane (methyl chloride)	30	10	10	520	10	1,000
91-58-7	Chloronaphthalene, 2-	600	1,000	1,000	1,000	1,000	1,000
95-57-8	Chlorophenol, 2- (o-chlorophenol)	40	10	10	280	10	5,200
7005-72-3	Chlorophenyl-phenylether, 4-	100	1,000	1,000	1,000	1,000	1,000
39638-32-9 (108-60-1)	Chloropropane, 1-(2,2-Oxybis) (2-chloroisopropylether)	100	10	10	2,300	10	10,000
94-49-8	Chlorotoluene, 2- (o-chlorotoluene)		160	160	160	560	560
106-43-4	Chlorotoluene, 4- (p-chlorotoluene)		1,000	1,000	1,000	1,000	1,000
108-39-4	Cresol, m- (3-methylphenol)	100	3,100	3,100	3,100	10,000	10,000
106-44-5	Cresol, p- (4-methylphenol)	100	2,800	2,800	2,800	10,000	10,000
98-82-8	Cumene (Isopropylbenzene; 1-methylethyl-benzene)	800	570	570	570	1,000	1,000
110-82-7	Cyclohexane	100	140	140	140	140	140
3073-66-3	Cyclohexane, 1,1,3-trimethyl	100	1,000	1,000	1,000	1,000	1,000
N/A	Cyclohexane, 2-butyl-1,1,3-t	100	1,000	1,000	1,000	1,000	1,000
1678-93-9	Cyclohexane, -butyl	100	1,000	1,000	1,000	1,000	1,000
1678-92-8	Cyclohexane, propyl	100	1,000	1,000	1,000	1,000	1,000
3788-32-7	Cyclopentane, 2-methylpropy	100	1,000	1,000	1,000	1,000	1,000
99-87-6	Cymene, p-	100	1,000	1,000	1,000	1,000	1,000
72-54-8	DDD, 4,4'-	0.1	3	3	3	12	12
72-55-9	DDE, 4,4'-		2	2	2	9	9
50-29-3	DDT, 4,4'-	0.1	2	2	2	9	9
319-86-8	delta-BHC (delta HCH)	100	10,000	10,000	10,000	10,000	10,000
132-64-9	Dibenzofuran	100	290	290	290	1,000	1,000
132-65-0	Dibenzothiophene	100	10,000	10,000	10,000	10,000	10,000
96-12-8	Dibromo-3-chloropropane, 1,2-	1	0.45	0.45	0.45	2	2
124-48-1	Dibromochloromethane	10	1	1	110	1	1,000
541-73-1	Dichlorobenzene, m- (1,3-dichlorobenzene)	600	100	100	5,100	100	10,000
95-50-1	Dichlorobenzene, o- (1,2-dichlorobenzene)	600	50	50	5,100	50	10,000
106-46-7	Dichlorobenzene, p- (1,4-Dichlorobenzene)	75	100	100	570	100	10,000
91-94-1	Dichlorobenzidine, 3,3-	60	2	2	2	6	6
75-71-8	Dichlorodifluoromethane (Freon 12)	1,000	94	94	94	310	310
75-34-3	Dichloroethane, 1,1-	70	10	10	570	10	1,000
107-06-2	Dichloroethane, 1,2-	2	1	1	6	1	24
540-59-0	Dichloroethene, 1,2-	10	1	1	79	1	1,000
156-60-5	Dichloroethene, 1,2-(trans)	100	50	50	1,000	50	1,000
75-35-4	Dichloroethylene, 1,1-	2	8	8	8	10	150
156-59-2	Dichloroethylene, cis, 1,2-	10	1	1	79	1	1,000

and AOC (see Appendix A), as well as to evaluate the nature and extent of potential releases at each yard. Approximately 80% of the soil **Table 6-1.Full RFI Soil and Groundwater Delineation Criteria**

CAS #	Compound Name	Site Specific Groundwater (µg/L)	Soil				
			Most Conservative (mg/kg)	Unsaturated PB (mg/kg)	Saturated PB (mg/kg)	Unsaturated On-Site (mg/kg)	Saturated On-Site (mg/kg)
75-09-2	Dichloromethane (methylene chloride)	2	1	1	49	1	210
120-83-2	Dichlorophenol, 2,4-	20	10	10	170	10	3,100
78-87-5	Dichloropropane, 1,2-	1	10	10	10	43	43
142-28-9	Dichloropropane, 1,3-		1,000	1,000	1,000	1,000	1,000
563-58-6	Dichloropropene, 1,1-		1,000	1,000	1,000	1,000	1,000
594-20-7	Dichloropropane, sec-		1,000	1,000	1,000	1,000	1,000
10061-01-5	Dichloropropene, cis-1,3-	5	1	1	4	1	5
10061-02-6	Dichloropropene, trans-1,3-	5	1	1	4	1	5
60-57-1	Dieldrin	0.03	0.042	0	0	0	0
84-66-2	Diethyl phthalate	5,000	50	50	10,000	50	10,000
57-97-6	Dimethybenz(a)anthracene, 7,12-	100	10,000	10,000	10,000	10,000	10,000
95-47-6	Dimethyl-benzene, 1,2 (o-Xylene)	100	1,000	1,000	1,000	1,000	1,000
590-50-1	Dimethyl 2-pentanone, 4-4-	100	10,000	10,000	10,000	10,000	10,000
1207-15-4	Dimethylbenzo(B,D)thio, 2,8-	100	1,000	1,000	1,000	1,000	1,000
105-67-9	Dimethylphenol (2,4-)	100	10	10	1,100	10	10,000
576-26-1	Dimethylphenol, 2,6-	100	38	38	38	380	380
108-68-9	Dimethylphenol, 3,5-	100	10,000	10,000	10,000	10,000	10,000
131-11-3	Dimethylphthalate	100	50	50	10,000	50	10,000
84-74-2	Di-n-butyl phthalate	900	100	100	5,700	100	10,000
534-52-1	Dinitro-2-methylphenol, 4,6-	100	7.8	7.8	7.8	100	100
51-28-5	Dinitrophenol, 2,4-	40	10	10	110	10	2,100
121-14-2	Dinitrotoluene, 2,4-	10	1	1	1	4	4
606-20-2	Dinitrotoluene, 2,6-	5	1	1	1	4	4
117-84-0	Di-n-octyl phthalate	100	100	100	1,100	100	10,000
959-98-8	Endosulfan I	0.4	50	50	340	50	6,200
33213-65-9	Endosulfan II	0.4	50	50	340	50	6,200
1031-07-8	Endosulfan sulfate	0.4	50	50	340	50	6,200
72-20-8	Endrin	2	17	17	17	50	310
104-76-7	Ethyl-1-hexanol, 2-	100	1000	1,000	1,000	1,000	1,000
1678-91-7	Ethylcyclohexane	100	1000	1,000	1,000	1,000	1,000
106-93-4	Ethylene dibromide (EDB; 1,2-dibromoethane)	0.05	0.0069	0	0	0	0
15438-31-0	Ferrous Iron						
68476-33-5	Fuel oil no. 6		10,000	10,000	10,000	10,000	10,000
8006-61-9	Gasoline	100	10,000	10,000	10,000	10,000	10,000
N	Hardness	250,000					
76-44-8	Heptachlor	0.4	0.15	0.15	0.15	0.65	0.65
1024-57-3	Heptachlor epoxide	0.2	0.07	0.07	0.07	0.3	0.3
592-27-8	Heptane, 2-Methyl	100	10,000	10,000	10,000	10,000	10,000
118-74-1	Hexachlorobenzene	10	0.66	0.66	0.66	2	2
87-68-3	Hexachlorobutadiene	1	1	1	1	21	21
77-47-4	Hexachlorocycloropentadiene	50	100	100	400	100	7300
67-72-1	Hexachloroethane	10	6	6	6	100	100
110-54-3	Hexane (n-Hexane)	30	110	110	110	110	110
591-78-6	Hexanone, 2-	100	3,100	3,100	3,100	10,000	10,000
123-42-2	Hydroxy-2-methyl-4-pentanone, 2-	100	1,000	1,000	1,000	1,000	1,000
95-13-6	Indene	100	10,000	10,000	10,000	10,000	10,000

and AOC (see Appendix A), as well as to evaluate the nature and extent of potential releases at each yard. Approximately 80% of the soil **Table 6-1.Full RFI Soil and Groundwater Delineation Criteria**

CAS #	Compound Name	Site Specific Groundwater (µg/L)	Soil				
			Most Conservative (mg/kg)	Unsaturated PB (mg/kg)	Saturated PB (mg/kg)	Unsaturated On-Site (mg/kg)	Saturated On-Site (mg/kg)
54832-83-6	Indene, 1H-		10,000	10,000	10,000	10,000	10,000
85-44-9	Isobenzofurandione, 1,3-	100	1,000	1,000	1,000	1,000	1,000
78-78-4	Isopentane	100	10,000	10,000	10,000	10,000	10,000
78-59-1	Isophorone	100	50	50	1,100	50	10,000
98-82-8	Isopropylbenzene (cumene; 1-methylethyl-benzene)	800	570	570	570	1,000	1,000
5989-27-5	Limonene (d-Limonene)	100	10,000	10,000	10,000	10,000	10,000
58-89-9	Lindane (gamma BHC; gamma HCH)	0.2	0.52	1	1	2	2
149-30-4	Mercamptobenzothiozole, 2-	5	17	17	17	59	59
126-98-7	Methacrylonitrile	100	2.1	2	2	8	8
74-82-8	Methane	100	1,000	1,000	1,000	1,000	1,000
79-20-9	Methyl Acetate	7,000	1,000	1,000	1,000	1,000	1,000
1705-85-57	Methyl Chrysene, 6-	100	10,000	10,000	10,000	10,000	10,000
98-82-8	Methylethyl-benzene, 1- (Isopropylbenzene, cumene)	800	570	570	570	1,000	1,000
78-93-3	Methyl ethyl ketone (2-Butanone)	300	50	50	1,000	50	1,000
108-10-1	Methyl-2-pentanone, 4- (methyl isobutyl ketone; MIBK)	400	50	50	1,000	50	1,000
141-79-7	Methyl-3-penten-2-one, 4-	100	10,000	10,000	10,000	10,000	10,000
108-87-2	Methylcyclohexane	100	1,000	1,000	1,000	1,000	1,000
590-67-0	Methylcyclohexanol, 1-	100	1,000	1,000	1,000	1,000	1,000
96-37-7	Methylcyclopentane	100	10,000	1,000	1,000	1,000	1,000
75-95-3	Methylene bromide	-	67	67	67	230	230
75-09-2	Methylene chloride (dichloromethane)	2	1	1	49	1	210
589-81-1	Methylheptane, 3-	100	1,000	1,000	1,000	1,000	1,000
591-76-4	Methylhexane, 2-	100	1,000	1,000	1,000	1,000	1,000
589-34-4	Methylhexane, 3-	100	1,000	1,000	1,000	1,000	1,000
107-83-5	Methyl-Pentane, 2-	100	1,000	1,000	1,000	1,000	1,000
96-14-0	Methylpentane, 3-	100	1,000	1,000	1,000	1,000	1,000
95-48-7	Methylphenol, 2- (o-cresol)	100	2,800	2,800	2,800	10,000	10,000
108-39-4	Methylphenol, 3- (m-cresol)	100	3,100	3,100	3,100	10,000	10,000
106-44-5	Methylphenol, 4- (p-cresol)	100	2,800	2,800	2,800	10,000	10,000
1634-04-4	MTBE	70	62	62	62	160	160
2958-76-1	Napthalene, decahydro-2-me	100	10,000	10,000	10,000	10,000	10,000
14797-55-8	Nitrate	10,000					
14797-65-0	Nitrite (as N)	1,000					
88-4-4	Nitroaniline, 2-	100	1.7	1.7	1.7	18	18
99-09-2	Nitroaniline, 3-	100	23	23	23	140	140
100-01-6	Nitroaniline, 4-	100	32	32	32	140	140
98-95-3	Nitrobenzene	10	10	10	28	10	520
88-75-5	Nitrophenol, 2-	100	10,000	10,000	10,000	10,000	10,000
100-02-7	Nitrophenol, 4-	100	1.7	1.7	630	1.7	10,000
86-30-6	N-Nitroso-di-n-propylamine	20	0.66	0.66	0.66	0.66	0.66
86-30-6	N-Nitrosodiphenylamine	20	100	100	140	100	600
17301-94-9	Nonane, 4-Methyl	100	10,000	1,000	1,000	1,000	1,000
95-13-6?	Octahydro-2,2,4,4-1H-Indene	100	10,000	10,000	10,000	10,000	10,000
2216-34-4	Octane, 4-methyl	100	10,000	1,000	1,000	1,000	1,000

and AOC (see Appendix A), as well as to evaluate the nature and extent of potential releases at each yard. Approximately 80% of the soil **Table 6-1.Full RFI Soil and Groundwater Delineation Criteria**

CAS #	Compound Name	Site Specific Groundwater (µg/L)	Soil				
			Most Conservative (mg/kg)	Unsaturated PB (mg/kg)	Saturated PB (mg/kg)	Unsaturated On-Site (mg/kg)	Saturated On-Site (mg/kg)
14265-44-2	Orthophosphate						
1336-36-3	PCBs	0.5	0.49	0.49	0.49	2	2
87-86-5	Pentachlorophenol	1	6	6	6	24	24
565-75-3	Pentane, 2, 3,4-trimethyl	100	10,000	1,000	1,000	1,000	1,000
109-66-0	Pentane, n-	100	10,000	1,000	1,000	1,000	1,000
77-74-7	Pentanol, 3-methyl-3-	100	1,000	1,000	1,000	1,000	1,000
565-69-5	Pentanone, 2-methyl, 3-	100	1,000	1,000	1,000	1,000	1,000
198-55-0	Perylene	-	10,000	10,000	10,000	10,000	10,000
832-69-9	Phenanthrene, 1-methyl-	100	10,000	10,000	10,000	10,000	10,000
N/A	Phenanthrene, 2,7-dimethyl	100	10,000	10,000	10,000	10,000	10,000
108-95-2	Phenol	4,000	50	50	10,000	50	10,000
6180-61-6	Phenoxyl 1-propanol, 3-	100	1,000	1,000	1,000	1,000	1,000
103-82-2	Phenylacetic acid	100	10,000	10,000	10,000	10,000	10,000
612-94-2	Phenylnaphthalene, 2-	100	10,000	10,000	10,000	10,000	10,000
7723-14-0	Phosphorus	0.73					
103-65-1	Propylbenzene, n-	100	240	240	240	240	240
91-22-5	Quinoline	5	0.16	0	0	1	1
111-02-4	Squalene	100	10,000	10,000	10,000	10,000	10,000
100-42-5	Styrene	100	23	23	23	97	97
14808-79-8	Sulfate	250,000					
N/A	Sulfide Reactivity						
N/A	TDS	500,000					
75-65-0	Tert-Butyl alcohol (TBA; 2-methyl- 2-propanol)	100	1,000	1,000	1,000	1,000	1,000
79-34-5	Tetrachloroethane, 1,1,2,2-	2	1	1	34	1	70
630-20-6	Tetrachloroethane, 1,1,1,2		1	1	170	1	310
127-18-4	Tetrachloroethylene	1	1	1	4	1	6
110-01-0	Thiophene, tetrahydro	100	10,000	10,000	10,000	10,000	10,000
1600-44-8	Thiophene, tetrahydro-, 1-ox	100	10,000	10,000	10,000	10,000	10,000
4740-00-5	Thiophene, tetrahydro-3-met	100	10,000	10,000	10,000	10,000	10,000
N/A	TOC						
N/A	TPH		1,000	1,000	1,000	1,000	1,000
87-61-6	Trichlorobenzene, 1,2,3-		1,000	1,000	1,000	1,000	1,000
120-82-1	Trichlorobenzene, 1,2,4-	9	68	68	68	100	1,200
71-55-6	Trichloroethane, 1,1,1-	30	50	50	210	50	1,000
79-00-5	Trichloroethane, 1,1,2-	3	1	1	22	1	420
79-01-6	Trichloroethylene	1	1	1	23	1	54
96-18-4	Trichloropropane, 1,2,3-		0.005	0.005	0.005	0.011	0.011
95-95-4	Trichlorophenol, 2,4,5-	700	50	50	5,600	50	10,000
88-06-2	Trichlorophenol, 2,4,6-	20	10	10	62	10	270
75-69-4	Trichlorofluoromethane (Freon 11)	2,000	390	390	390	1,000	1,000
76-13-1	Trichlorotrifluoroethane (Freon 113)	100	1,000	1,000	1,000	1,000	1,000
95-63-6	Trimethyl benzene, 1,2,4-	100	52	52	52	170	170
526-73-8	Trimethylbenzene, 1,2,3-	100	1,000	1,000	1,000	1,000	1,000
108-67-8	Trimethyl-benzene, 1,3,5-	100	21	21	21	70	70
75-01-4	Vinyl chloride	5	2	2	2	7	7
68476-30-2	No. 2 Fuel Oil	100	10,000	10,000	10,000	10,000	10,000

~~and AOC (see Appendix A), as well as to evaluate the nature and extent of potential releases at each yard. Approximately 80% of the soil~~ ~~**Table 6-1.Full RFI Soil and Groundwater Delineation Criteria**~~

~~CAS #~~	~~Compound Name~~	~~Site Specific Groundwater (µg/L)~~	~~Soil~~				
			~~Most Conservative (mg/kg)~~	~~Unsaturated PB (mg/kg)~~	~~Saturated PB (mg/kg)~~	~~Unsaturated On-Site (mg/kg)~~	~~Saturated On-Site (mg/kg)~~

~~PB = Property Boundary~~

~~samples (e.g., 665 of 830 samples) were~~Table 6-~~2~~ 1 summarizes the constituents that were detected in soil samples collected during the Full RFI:

Table 6-~~2~~1. Constituents Detected in Full RFI Soil Samples

Detected VOCs	Detected SVOCs	Detected Total Metals
Greater Than Applicable Delineation Criteria		
Benzene	2,4-Dimethylphenol	Aluminum
Cyclohexane	Benzo(a)anthracene	Antimony
Ethylbenzene	Benzo(a)pyrene	Arsenic
Isopropylbenzene	Benzo(b)fluoranthene	Barium
Toluene	Benzo(k)fluoranthene	Copper
Xylenes (total)	Bis(2-ethylhexyl)phthalate	Iron
	Carbazole	Lead
	Dibenzo(a,h)anthracene	Manganese
	Indeno(1,2,3-cd)pyrene	Nickel
	Naphthalene	Vanadium
		Zinc
Less Than Applicable Delineation Criteria		
1,1,1-Trichloroethane	2,6-Dinitrotoluene	Beryllium
1,1,-Dichloroethane	2-Methylnaphthalene	Cadmium
1,1-Dichloroethylene	2-Methylphenol	Calcium
1,2,4-Trichlorobenzene	3,3-Dichlorobenzidine	Chromium
1,2-Dichlorobenzene	4-Methylphenol	Cobalt
1,4-Dichlorobenzene	Acenaphthene	Magnesium
Acetone[8]	Acenaphthylene	Mercury
Carbon disulfide	Anthracene	Potassium
Chlorobenzene	Atrazine	Selenium
Methyl ethyl ketone	Benzaldehyde	Silver
Methyl acetate	Benzo(g,h,i)perylene	Sodium
Methyl tert-butyl ether	Biphenyl	Thallium
Methylcyclohexane	Butylbenzylphthalate	TOL
Methylene chloride	Caprolactam	
Styrene	Chrysene	
Tetrachloroethylene	Dibenzofuran	
Tichlorofluoromethane	Diethylphthalate	
Trichloroethylene	Dimethylphthalate	
Vinyl chloride	Di-n-butylphthalate	
	Di-n-octyl phthalate	
~~Vinyl chloride~~	Fluoranthene	
	Fluorene	
	Hexachlorocyclopentadiene	
	n-Nitrosodiphenylamine	

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[8]The maximum concentration of acetone (110 mg/kg) exceeded the IGWSCC for acetone (100 mg/kg), but not the RDCSCC (1000 mg/kg). However, the only sample which contained more than 100 mg/kg of acetone was collected from the saturated zone. Therefore, the most conservative ~~criteria~~ criterion would not be applicable.

Table 6-~~2~~1. Constituents Detected in Full RFI Soil Samples

Detected VOCs	Detected SVOCs	Detected Total Metals
	Phenanthrene Phenol Pyrene	

Table 6-2 summarizes the 37 constituents that were detected ~~Approximately 30 constituents were detected~~ above their respective delineation criteria in any soil ~~samples~~ sample collected, ~~during~~ including 1st-Phase RFI soil samples, the

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Table 6-2. Exceedances of Soil Delineation Criteria

COC Detected Above Delineation Criteria	DELINEATION CRITERIA			SITEWIDE				NORTH FIELD/MAIN YARD				CENTRAL YARD				EAST YARD			
	Impact to Groundwater	Residential Direct Contact	Non-Residential Direct Contact	Maximum Concentration	Number of Exceedances	Number of Samples	% Exceeded	Maximum Concentration	Number of Exceedances	Number of Samples	% Exceeded	Maximum Concentration	Number of Exceedances	Number of Samples	% Exceeded	Maximum Concentration	Number of Exceedances	Number of Samples	% Exceeded
VOCs (mg/kg)																			
Benzene	1	3	13	26,000	88	744	**12%**	**26,000**	57	370	**15%**	8.36	5	156	3%	750	26	218	**12%**
Benzenethiol		1	20	99	10	220	**5%**	73	7	95	**7%**	22	1	64	2%	**99**	2	61	3%
Cyclohexane		140	140	370	5	448	1%	**370**	4	344	1%	--	0	82	0%	150	1	117	1%
Ethylbenzene	100	1,000	1,000	160,000	10	744	1%	**160,000**	9	370	2%	--	0	156	0%	170	1	218	0%
Hexane		110	110	140	1	448	0.2%	--	0	344	0%	--	0	82	0%	140	1	117	1%
Isopropylbenzene		570	1,000	600	1	448	0.2%	**600**	1	344	0.3%	--	0	82	0%	--	0	117	0%
Toluene	500	1,000	1,000	9,700	6	744	1%	**9,700**	5	370	1%	--	0	156	0%	2,400	1	218	0%
Xylenes	67	410	1,000	220,000	33	744	4%	**220,000**	26	370	**7%**	303	2	156	1%	2,300	5	218	2%
1,2,4-Trimethylbenzene		52	170	160	1	448	0.2%	**160**	1	344	0.3%	--	0	82	0%	--	0	117	0%
SVOCs (mg/kg)																			
Benzo(a)anthracene		0.9	4	54	75	727	**10%**	**54**	57	362	**16%**	12	10	177	**6%**	34	8	188	4%
Benzo(a)pyrene		0.66	0.66	71	85	727	**12%**	**71**	58	362	**16%**	17	11	177	**6%**	38	16	188	**9%**
Benzo(b)fluoranthene		0.9	4	40	61	727	**8%**	36	44	362	**12%**	12	9	177	**5%**	**40**	8	188	4%
Benzo(k)fluoranthene		0.9	4	19	17	727	2%	13	8	362	2%	4	5	177	3%	**19**	4	188	2%
Carbazole	0.6	24	96	2.3	4	448	1%	**2.3**	3	362	1%	0.63	1	82	1%	--	0	117	0%
Chrysene		62	230	86	1	727	0.1%	**86**	1	362	0.3%	--	0	177	0%	--	0	188	0%
Dibenzo(a,h)anthracene		0.66	0.66	4.9	16	727	2%	**4.9**	10	362	3%	1.8	4	177	2%	1.1	2	188	1%
Indeno(1,2,3-cd)pyrene		0.9	4	11	21	727	3%	**11**	13	362	4%	5.3	6	177	3%	1.1	2	188	1%
Pyrene	100	1,700	10,000	110	1	727	0.1%	0	0	362	0%	--	0	177	0%	**110**	1	188	1%
Quinoline		0.16	1	0.71	2	244	1%	**0.71**	2	267	1%	--	0	87	0%	--	0	62	0%
Naphthalene	100	230	4,200	450	4	727	1%	**450**	3	362	1%	--	0	177	0%	170	1	188	1%
Bis(2ethylhexyl) phthalate	100	49	210	1,300	2	689	0.3%	--	0	344	0%	--	0	169	0%	**1,300**	2	176	1%
2,4-Dimethylphenol	10	1,100	10,000	110	6	696	1%	110	4	350	1%	16	2	170	1%	--	0	176	0%
Phenol	50	10,000	10,000	67	1	696	0.1%	--	0	350	0%	67	1	170	1%	--	0	176	0%
Metals (mg/kg)																			
Aluminum*		76,000	100,000	97,300	3	345	1%	**97,300**	3	202	1%	--	0	48	0%	--	0	95	0%
Antimony		14	340	228	22	461	**5%**	**228**	11	249	4%	225	3	81	4%	161	8	131	**6%**
Arsenic		20	20	117	78	506	**15%**	**117**	34	263	**13%**	43.4	8	91	**9%**	83.2	36	151	**24%**
Barium*		700	47,000	2,120	1	461	0.2%	--	0	249	0%	**2,120**	1	81	1%	--	0	131	0%
Beryllium		16	200	40	1	461	0.2%	--	0	249	0%	**39.7**	1	81	1%	--	0	131	0%
Copper		600	600	3,450	16	475	3%	3,450	14	257	**5%**	--	0	81	0%	1,000	2	137	1%
Iron*		23,000	100,000	345,000	169	345	**49%**	191,000	96	202	**48%**	84,800	15	48	**31%**	**345,000**	58	95	**61%**
Lead		400	600	145,000	78	712	**11%**	8,450	41	345	**12%**	11,000	13	163	**8%**	**145,000**	24	204	**12%**
Manganese*		1,800	19,000	2,470	2	345	1%	--	0	202	0%	**2,470**	1	48	2%	1,830	1	94	1%

Table 6-2. Exceedances of Soil Delineation Criteria

COC Detected Above Delineation Criteria	DELINEATION CRITERIA			SITEWIDE				NORTH FIELD/MAIN YARD				CENTRAL YARD				EAST YARD			
	Impact to Groundwater	Residential Direct Contact	Non-Residential Direct Contact	Maximum Concentration	Number of Exceedances	Number of Samples	% Exceeded	Maximum Concentration	Number of Exceedances	Number of Samples	% Exceeded	Maximum Concentration	Number of Exceedances	Number of Samples	% Exceeded	Maximum Concentration	Number of Exceedances	Number of Samples	% Exceeded
Mercury		14	270	29	1	461	0.2%	**29**	1	249	0.4%	--	0	81	0%	--	0	131	0%
Nickel		250	2,400	3,080	7	463	2%	1,550	5	249	2%	**3,080**	1	83	1%	294	1	131	1%
Vanadium		370	7,100	3,740	9	461	2%	3,740	9	249	4%	--	0	81	0%	--	0	131	0%
Zinc		1,500	1,500	10,500	5	369	1%	**10,500**	4	202	2%	4,860	1	56	2%	--	0	99	0%
TOL/TEL		2	2	2,400	52	326	**16%**	360	38	164	**23%**	3.45	2	82	2%	**2,400**	12	80	**15%**
SPLP Metals (mg/L)																			
SPLP aluminum*	2.2			7.79	8	32	**25%**	6.68	6	20	**30%**	**7.79**	2	6	**33%**	--	0	6	0%
SPLP iron*	3.3			14.9	9	32	**28%**	**14.9**	7	20	**35%**	5.95	2	6	**33%**	--	0	6	0%
SPLP antimony	0.22			1.6	2	32	**6%**	**1.6**	2	20	**10%**	--	0	6	0%	--	0	6	0%
SPLP lead	0.11			0.68	2	48	4%	0.123	1	29	3%	--	0	10	0%	**0.68**	1	9	**11%**

Indicator COCs and maximum concentrations are highlighted in bold
Exceedances of 5% or greater are highlighted in bold
*Naturally occurring metals
Concentrations in blue equal/exceed Residential Direct Contact Criteria
Concentrations in red equal/exceed Non-Residential Direct Contact Criteria
Concentrations in black equal/exceed Impact to Groundwater Criteria
--Not detected above applicable delineation criteria

Phase II OWSS soil samples and full~~the full~~ RFI soil samples. This table shows the maximum concentration detected, the total number of times the analyte exceeded the applicable criterion, the total number of samples that were analyzed for the analyte and the relative frequency of exceedances (e.g. percent of samples that had an exceedance versus the number of samples that were analyzed). A breakdown of exceedances in samples collected in each of the three main areas (North Field/Main Yard, Central Yard and East Yard) is also provided on Table 6-2.

As shown on Table 6-2, m~~M~~any of the chemicals (65%) were detected infrequently (e.g., detected in 5% or less of the samples analyzed). The most commonly detected chemicals that were also detected above their respective delineation criteria include: benzene (the criterion was exceeded in approximately 12% of the samples), PAHs, (primarily benzo(a)pyrene (the criterion was exceeded in approximately 12% of the samples), and metals (lead, TEL/TOL, arsenic, and iron). The lead criterion was exceeded in 11% of the samples, the TEL/TOL criterion was exceeded in 16% of the samples that were analyzed for TEL/TOL, and the arsenic criterion was exceeded in 15% of the samples. Iron was exceeded in 49% of the samples. Five compounds have been selected as indicator COCs to illustrate the nature and extent of impacted soils at the Refinery:

- Benzene and benzo(a)pyrene are used to represent the degree of organic impacts because they are detected the most frequently in all areas of the Refinery, and because either benzene and/or benzo(a)pyrene was present above applicable soil delineation criteria in 98.5% of all samples that contained organic COCs above applicable delineation criteria.
- TEL/TOL and lead were frequently detected above the delineation criteria at confirmed TEL sites.
- Arsenic is included as an indicator COC because it was detected in many of the samples; however, it is believed to be naturally-occurring and not related to facility activities, as discussed below.

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Iron was also commonly detected above the residential delineation criteria based on EPA residential soil screening levels (SSLs) in both fill and native soils (e.g., 49% of the samples that were analyzed for iron), but rarely above EPA industrial/commercial SSLs. There is no apparent correlation between iron concentrations and SWMUs and AOCs; therefore, iron is also believed to be naturally elevated and not related to site waste management activities.

Although arsenic has been detected in many of the soil samples from the Refinery, 85% of the samples contained ~~concentrations of~~ arsenic at concentrations ~~are usually~~ less than 20 mg/kg, which is generally considered to be background in New Jersey soils, as represented by the NJDEP SCC for both residential and industrial land use (Sanders, 2003). The maximum detected concentration of arsenic was 117 mg/kg in RFI soil samples. It should be noted that the Refinery borders the American Smelting and Refining Company, and elevated metals in this area may be attributable to windblown dust from the adjacent property. Alternatively, these higher concentrations may represent background concentrations as well, since elevated arsenic soil concentrations have been

found to be naturally occurring in New Jersey (e.g., glauconite-rich clay) where total arsenic levels have been reported to range from 13 to 131 mg/kg (Sanders, 2003). Therefore, arsenic is not considered to be a Facility-related COC.

Table 6-3 provides an overview of the types of constituents that were detected at each SWMU and AOC. The table summarizes where the major categories of COCs have been detected above applicable criteria (e.g., surface soils, subsurface soils and native material), and what criteria have been exceeded: residential direct contact criteria (blue checkmark), non-residential direct contact criteria (red checkmark), or impact to groundwater criteria (green checkmark, applicable to unsaturated soils only). SWMUs and AOCs are highlighted in pink, blue or green, depending on whether they are located in the North Field/Main Yard, Central Yard or East Yard, respectively. The SWMUs and AOCs are prioritized according to the following categories:

- Identified LNAPL areas for which additional IRMs are planned;
- LNAPL areas that will be evaluated further in the CMS;
- Confirmed TEL burial sites (e.g., SWMUs and AOCs where TOL/TEL has been detected);
- SWMUs and AOCs where lead has been detected above the delineation criterion, but TEL has not, and which do not overlap with LNAPL areas;
- SWMUs and AOCs where VOCs have been detected above the delineation criteria, but lead and TEL/TOL have not been detected above criteria, and which do not overlap with LNAPL areas;
- SWMUs and AOCs where PAHs have been detected above delineation criteria, but VOCs, lead and TEL/TOL have not been detected above delineation criteria and which do not overlap with LNAPL areas;
- SWMUs and AOCs where other COC metals (not including lead) have been detected but VOCs, SVOCs, lead and TEL/TOL have not been detected above delineation criteria and which do not overlap with LNAPL areas; and
- SWMUS and AOCs where there have been no exceedances of soil delineation criteria, no further action is necessary, or that are undergoing closure.

In general, all of the SWMUs and AOCs (except for those that fall within the last two categories) will be included in the CMS for further evaluation, such as the use of engineered barriers, deed restrictions (especially for PAH exceedances) and/or other appropriate remediation measures (such as confirmed TEL sites).

~~The~~A discussion of the nature and extent of ~~compounds~~ COCs in each yard ~~or area~~ is provided below. More detailed discussions related to each SWMU can be found in Appendix A.

Table 6-3. Constituents Detected at SWMUs and AOCs

SWMU/AOC	VOCs				SVOCs				TEL/TOL			Lead			Arsenic			Other Metals		
	Surface Soils	Suburface Soils	Impact to Groundwater (Unsaturated Soils)	Native Soils	Surface Soils	Suburface Soils	Impact to Groundwater (Unsaturated Soils)	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Suburface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Suburface Soils	Native Soils
SWMUS AND AOCS WHERE LNAPL HAS BEEN MEASURED THAT ARE RECOMMENDED FOR IRM IMPLEMENTATION																				
SMWU 43 (SWMA 3)						√√														
AOC 8																				
AOC 15 (see NF6)		√√	√																	
AOC 16 (NF2)			√			√√														
AOC 16 (NF5)																				
AOC 16 (NF6)																				
AOC 19						√√										√√				
AOC 25																				
AOC 14 (EY4B)		√√				√√							√√		√√	√√				
AOC 16 (EY4)	√	√√	√		√√	√√							√√		√√	√√			√	
AOC 26 (EY4B)	√	√√	√		√√	√√									√√	√√				
AOC 29																				
SWMUS AND AOCS WHERE LNAPL HAS BEEN MEASURED WHICH WILL BE EVALUATED DURING THE CMS																				
SWMU 40						√√							√						√√	
SWMU 41		√√	√			√√							√√			√√		√	√√	
AOC 16 (NF3)																				
AOC 16 (NF 4)																				
SWMU 42																				
AOC 16 (EY1)							√					√√						√		
AOC 16 (EY3)																				
AOC 6B (EY4A)			√										√√			√√		√		
AOC 28					√√															
CONFIRMED TEL BURIAL SITES																				
SWMA 1	√	√	√		√√	√√	√		√√	√√		√√	√√		√√	√√	√√	√√	√√	
SWMU 6		√√		√√		√√			√√	√√			√√							

Table 6-3. Constituents Detected at SWMUs and AOCs

	VOCs				SVOCs				TEL/TOL			Lead			Arsenic			Other Metals		
SWMU/AOC	Surface Soils	Suburface Soils	Impact to Groundwater (Unsaturated Soils)	Native Soils	Surface Soils	Suburface Soils	Impact to Groundwater (Unsaturated Soils)	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Suburface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Suburface Soils	Native Soils
SWMU 7		√				√√				√√			√√					√√	√√	
SWMU 16		√√		√√		√√				√√			√			√√	√√		√√	
SWMU 17	√√	√√	√	√√		√√		√	√√	√√		√	√√							
SWMU 18	√√	√√	√	√√			√	√	√√	√√			√√							
SWMU 19		√√	√		√√	√√	√			√√										
SWMU 20	√	√√	√						√√	√√		√√	√√			√√	√√			
SWMU 22		√√				√√	√			√√	√√									
AOC 23		√√	√							√√		√√	√√		√√	√√		√	√	
SWMU 11A					√√					√√			√√							
SWMU 12		√	√				√			√√			√√							
SWMU 8		√√	√		√√	√√		√√	√√	√√	√√	√√	√√	√√						
SWMU 10		√√	√		√√				√√	√√		√√	√√		√√	√√			√√	
SWMU 26					√√					√√	√√	√			√√			√		
AREAS WITH ELEVATED LEAD CONCENTRATIONS, BUT NO TEL/TOL																				
SWMU 24		√√	√	√√					nc			√				√√	√√			
SWMU 35		√	√			√√							√			√√			√√	
SWMU 53						√√							√						√	
AOC 6A			√		√√	√√						√				√√				
AOC 21		√√				√√							√			√√			√√	
AOC 33						√√							√√					√	√√	
AOC 34		√	√										√			√√			√	
SWMU 36					√√							√			√√					
AOC 6C												√			√√			√		
AOC 31		√	√	√								√√	√		√√	√√		√		
SWMU 15			√										√√							
SWMU 34		√	√	√	√√	√√							√√	√√		√√	√√	√	√√	√√

Table 6-3. Constituents Detected at SWMUs and AOCs

SWMU/AOC	VOCs				SVOCs				TEL/TOL			Lead			Arsenic			Other Metals		
	Surface Soils	Suburface Soils	Impact to Groundwater (Unsaturated Soils)	Native Soils	Surface Soils	Suburface Soils	Impact to Groundwater (Unsaturated Soils)	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Suburface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Suburface Soils	Native Soils
AREAS WITH BTEX, BUT NO TEL/TOL OR ELEVATED LEAD																				
SWMA 2			√		√√	√√	√	√√										√		
AOC 10			√			√√														
AOC 16 (MY1)			√		√√	√√														
AOC 18		√																		
AOC 16 (CY4)		√√			√√	√√	√													
AOC16 (EY2)			√																	
AOC 27		√	√													√√				
AOC 13						√										√√	√√			
AREAS WITH PAHS GREATER THAN CRITERIA, BUT NO BTEX, TEL/TOL OR LEAD																				
AOC 17						√√														
AOC 16 (CY3)					√√	√√														
AOC 30					√															
AOC 28					√√															
AREAS WHERE THE ONLY EXCEEDANCES ARE ARSENIC OR OTHER METALS																				
AOC 16 (MY3)																			√	
AOC 32																			√	√
AOC 35															√√	√√		√		
SWMU 44	NO EXCEEDANCES																			
AOC 1	NO EXCEEDANCES																			
AOC 2	NO EXCEEDANCES																			
AOC3	NO EXCEEDANCES																			
AOC 9A	NO EXCEEDANCES																			
AOC 9B	NO EXCEEDANCES																			
AOC 16 (MY2)	NO EXCEEDANCES																			
AOC 16 (MY4)	NO EXCEEDANCES																			

Table 6-3. Constituents Detected at SWMUs and AOCs

SWMU/AOC	VOCs				SVOCs				TEL/TOL			Lead			Arsenic			Other Metals		
	Surface Soils	Suburface Soils	Impact to Groundwater (Unsaturated Soils)	Native Soils	Surface Soils	Suburface Soils	Impact to Groundwater (Unsaturated Soils)	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Suburface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Suburface Soils	Native Soils
AOC 16 (MY5)	NO EXCEEDANCES																			
AOC 16 (MY6)	NO EXCEEDANCES																			
AOC 16 (MY7)	NO EXCEEDANCES																			
AOC 24	NO EXCEEDANCES																			
SWMU 11B	NO EXCEEDANCES																			
SWMU 13	NO EXCEEDANCES																			
SWMU 14	NO EXCEEDANCES																			
SWMU 52	NO EXCEEDANCES																			
AOC 16 (CY2)	NO EXCEEDANCES																			
AOC 16 (CY5)	NO EXCEEDANCES																			
AOC 16 (CY6)	NO EXCEEDANCES																			
AOC 22	NO EXCEEDANCES																			
SWMU 9	NO EXCEEDANCES																			
SWMU 25	NO EXCEEDANCES																			
AOC 16 (EY5)	NO EXCEEDANCES																			
AOC 16 (EY6)	NO EXCEEDANCES																			
SWMU 1	UNDERGOING CLOSURE																			
SWMU 2	UNDERGOING CLOSURE																			
SWMU 31	NFA PER HWSA PERMIT																			
SWMU 51	NFA PER HWSA PERMIT																			
SWMU 3	UNDERGOING CLOSURE																			
SWMU 32	NFA PER HWSA PERMIT																			
SWMU 45	NFA PER HWSA PERMIT																			

Central Yard — SWMU 43 — LNAPL Area — √ Applicable Residential Direct Contact Criteria Exceeded

North Field/Main Yard — SWMA 1 — RFI Area — √ Applicable Non-Residential Direct Contact Criteria Exceeded

East Yard — SWMU 1 — No Further Action Required — √ Applicable Impact to Groundwater Criteria Exceeded

nc = Analyte detected in first round of sampling, but not confirmed in second round.

6.3.2 North Field/Main Yard

The SWMUs and AOCs in the North Field/Main Yard are in close proximity to one another. Therefore, it is difficult to attribute groundwater contamination and in some cases soil contamination to individual SWMUs as sources. One reason is that similar wastes were managed in the SWMUs, so the areas of contamination are often not readily distinguishable by the distribution of contaminants within them. In addition, the North Field/Main Yard has been used for petroleum-related activities ~~for many years~~since the late 1800's, and much of this area has been filled with petroleum impacted soils, catalyst beads and other fill materials. A peat/clay layer underlies much of the fill in this portion of the Refinery. Generally, this layer has not been impacted by petroleum-related activities, although in some areas heavily impacted by LNAPL, potential petroleum impacts have been identified in the peat.
~~The North Field/Main Yard has been used for petroleum-related activities since the late 1800's, and much of the East Yard has been filled with petroleum impacted soils and other fill material.~~

As discussed in more detail in Section 7, ten LNAPL areas have been identified in the North Field/Main Yard. These LNAPL areas are often associated with fill, which contains flyash, probably because this material is more porous than other types of fill.

~~A peat/clay layer underlies much of the fill in this portion of the Refinery. Generally, this layer has not been impacted by petroleum-related activities, although in some areas heavily impacted by LNAPL, potential petroleum impacts have been identified in the peat.~~

Approximately 48% of the soil samples (~~397~~ 398 samples) were collected in the North Field/Main Yard. ~~Approximately~~ Of these, 77 soil samples were collected during the 1st-Phase Soils Investigation, ~~21~~ 22 samples were collected during the OWSS investigations and 299 samples were collected during the first and second iterations of the Full RFI. Most of the samples (approximately ~~299~~ 300 samples) were collected within the fill layer. The remaining 97 samples were collected in the native material underlying the fill layer. Approximately 108 of the fill samples were surface soil samples (zero to two feet bgs).

Most of the samples (approximately 370 samples) were analyzed for Skinner's List VOCs, TCL VOCs and/or BTEX. Approximately ~~361~~ 362 samples were analyzed for Skinner's List SVOCs, TCL SVOCs, phenols and/or PAHs. Approximately 249 samples were analyzed for metals, an additional 96 samples were analyzed for lead, and 164 samples were analyzed for TEL/TOL. Any exceedances of the respective delineation criteria for each sample are shown on the summary tables that have been prepared for each SWMU and AOC (see Appendix A).

~~Table 6-3 provides an overview of the types of constituents that were detected at each SWMU and AOC. The SWMUs and AOCs are arranged according to whether they are identified LNAPL areas for which additional IRMs are planned, LNAPL areas that will be evaluated further in the CMS, confirmed TEL burial sites, etc.~~ A more detailed

summary of the COCs that were detected in each North Field/Main Yard SWMU and AOC is provided in Table 6-4. This table shows whether the area is located near the property boundary, whether it is associated with an LNAPL area, whether there is evidence of petroleum-impacted soils, maximum concentrations of COCs that were detected above criteria in surface soils, subsurface soils, native soils and groundwater, an indication of whether surface water/sediments may have been impacted, and a recommendation as to whether the SWMU or AOCs should be included in the CMS for further evaluation. If any COC was detected above applicable soil delineation criteria in any sample from a given SWMU/AOC, then the SWMU/AOC is recommended for further evaluation in the CMS. A complete discussion of each SWMU and AOC located in the North Field/Main Yard can be found in Appendix A.2.

Figures 6-~~2~~ 1 through 6-~~16~~ 15 show the distribution of samples analyzed for benzene, benzo(a)pyrene, lead, TOL/TEL and arsenic, as well as the relative concentration levels for each of these indicator COCs. These figures show the sampling results for each sample ~~distribution of each~~ for each of the indicator COCs in surface soils (zero to two feet bgs), in the intermediate layer (two to 10 feet bgs) and in deep soils (greater than 10 feet bgs). The delineation of these exceedances is also indicated by the shaded areas on these figures. Delineation was completed by using professional judgment, including delineation to a sample location where the indicator COC was less than the applicable delineation criterion, using the edge of a physical barrier, such as a tank or tank basin (when appropriate), and/or using a decreasing concentration gradient to estimate the edge of the impacted area.

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~~Table 6-3. Constituents Detected at SWMUs and AOCs~~

Commented [s1]: Candace, Please insert revised table.

~~SWMU/ AOC~~	~~VOCs~~				~~SVOCs~~				~~TEL/TOL~~			~~Lead~~			~~Arsenic~~			~~Iron~~			~~Other Metals~~		
	~~Surface Soils~~	~~Subsurface Soils~~	~~Impact to Groundwater (Unsaturated Soils)~~	~~Native Soils~~	~~Surface Soils~~	~~Subsurface Soils~~	~~Impact to Groundwater (Unsaturated Soils)~~	~~Native Soils~~	~~Surface Soils~~	~~Subsurface Soils~~	~~Native Soils~~	~~Surface Soils~~	~~Subsurface Soils~~	~~Native Soils~~	~~Surface Soils~~	~~Subsurface Soils~~	~~Native Soils~~	~~Surface Soils~~	~~Subsurface Soils~~	~~Native Soils~~	~~Surface Soils~~	~~Subsurface Soils~~	~~Native Soils~~
~~SWMUS AND AOCS WHERE LNAPL HAS BEEN MEASURED THAT ARE RECOMMENDED FOR IRM IMPLEMENTATION~~																							
~~SMWU 43 (SWMA 3)~~						√√																	
~~AOC 8~~																							
~~AOC 15 (see NF6)~~		√√	√																				
~~AOC 16 (NF2)~~			√			√√																	
~~AOC 16 (NF5)~~																							
~~AOC 16 (NF6)~~																							
~~AOC 19~~						√√										√√		√	√	√			
~~AOC 25~~																							
~~AOC 14 (EY4B)~~		√√	√		√√	√√							√√		√√	√√			√	√			
~~AOC 16 (EY4)~~	√	√√	√		√√	√√							√√		√√	√√			√	√		√	
~~AOC 26 (EY4B)~~	√	√√	√		√√	√√							√√		√√	√√							
~~AOC 29~~																							
~~SWMUS AND AOCS WHERE LNAPL HAS BEEN MEASURED WHICH WILL BE EVALUATED DURING THE CMS~~																							
~~SWMU 40~~													√					√	√	√		√√	
~~SWMU 41~~		√√	√			√√							√√			√√	√√	√	√	√	√	√√	
~~AOC 16 (NF3)~~																							
~~AOC 16 (NF 4)~~																							
~~SWMU 42~~												√√						√	√	√	√		
~~AOC 16 (EY1)~~							√					√√						√	√	√	√		
~~AOC 16 (EY3)~~																							
~~AOC 6B (EY4A)~~			√										√√			√√					√		
~~AOC 28~~					√√																		

~~Table 6-3. Constituents Detected at SWMUs and AOCs~~

SWMU/ AOC	VOCs				SVOCs				TEL/TOL			Lead			Arsenic			Iron			Other Metals		
	Surface Soils	Subsurface Soils	Impact to Groundwater (Unsaturated Soils)	Native Soils	Surface Soils	Subsurface Soils	Impact to Groundwater (Unsaturated Soils)	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils
CONFIRMED TEL BURIAL SITES																							
SWMA 1	√	√	√		√√	√√	√		√√	√√		√√	√√		√√	√√	√√	√	√	√	√√	√√	
SWMU 6		√√		√√		√√		√	√√	√√			√√										
SWMU 7		√				√√				√√			√√							√	√√	√√	
SWMU 16		√√	√	√		√√	√			√√			√			√√	√√		√	√		√√	
SWMU 17	√√	√√	√	√√		√√	√	√	√√	√√		√	√√										
SWMU 18	√√	√√	√	√√			√	√	√√	√√			√√										
SWMU 19		√				√√	√			√√						√√							
SWMU 20	√	√√	√						√√	√√		√√	√√			√√	√√		√	√			
SWMU 22		√√				√√	√			√√													
AOC 23		√√	√							√√		√√	√√		√√	√√			√√	√	√	√	
SWMU 11A					√√					√√			√√										
SWMU 12		√	√				√			√√			√√										
SWMU 8		√√	√		√√	√√	√	√√	√√	√√	√√	√√	√√	√√									
SWMU 10		√√	√		√√				√√	√√		√√	√√	√√	√√	√√	√√		√√			√√	
SWMU 26					√√					√√									√				
AREAS WITH ELEVATED LEAD CONCENTRATIONS, BUT NO TEL/TOL																							
SWMU 24		√√	√	√√					ne				√			√√	√√		√	√			
SWMU 35		√	√			√√	√						√			√√		√	√	√		√√	
SWMU 53						√√							√									√	
AOC 6A			√		√√	√√						√				√√		√	√	√			
AOC 21		√√				√√							√			√√			√			√√	
AOC 34		√	√										√		√√	√√			√	√		√	
SWMU 36					√√							√			√√			√	√				
SWMU 42												√√						√	√	√	√		
AOC 6C												√			√√			√	√	√	√		
AOC 31		√	√									√√	√		√√	√√		√	√	√	√		
SWMU 15			√										√√										
SWMU 34		√	√	√	√√	√√							√√	√√		√√	√√	√	√	√		√√	√
AREAS WITH BTEX, BUT NO TEL/TOL OR ELEVATED LEAD																							
SWMA 2			√		√√	√√													√	√	√		
AOC 10			√			√√													√				
AOC 15		√√	√																				
AOC 16 (MY1)			√		√√	√√																	
AOC 18		√																	√				
AOC 16 (CY4)		√√			√√	√√	√											√					
AOC16 (EY2)			√																				
AOC 27		√	√				√									√√			√	√			
AOC 13		√	√													√√		√	√				
AREAS WITH PAHS GREATER THAN CRITERIA, BUT NO BTEX, TEL/TOL OR LEAD																							
AOC 17						√√																	

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Table 6-3. Constituents Detected at SWMUs and AOCs

SWMU/ AOC	VOCs				SVOCs				TEL/TOL			Lead			Arsenic			Iron			Other Metals		
	Surface Soils	Subsurface Soils	Impact to Groundwater (Unsaturated Soils)	Native Soils	Surface Soils	Subsurface Soils	Impact to Groundwater (Unsaturated Soils)	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils
AOC 33						√√												√	√	√		√√	
AOC 16 (CY3)					√√	√√																	
AOC 30					√																		
AOC 28					√√																		
AREAS WHERE THE ONLY EXCEEDANCES ARE ARSENIC OR OTHER METALS																							
AOC 16 (MY3)																						√	
AOC 32																		√	√	√		√	√
AOC 35															√√	√√		√	√	√			

Table 6-3. Constituents Detected at SWMUs and AOCs

SWMU/ AOC	VOCs				SVOCs				TEL/TOL			Lead			Arsenic			Iron			Other Metals		
	Surface Soils	Subsurface Soils	Impact to Groundwater (Unsaturated Soils)	Native Soils	Surface Soils	Subsurface Soils	Impact to Groundwater (Unsaturated Soils)	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils
SWMU 44	NO EXCEEDANCES																						
AOC 1	NO EXCEEDANCES																						
AOC 2	NO EXCEEDANCES																						
AOC3	NO EXCEEDANCES																						
AOC 9A	NO EXCEEDANCES																						
AOC 9B	NO EXCEEDANCES																						
AOC 16 (MY4)	NO EXCEEDANCES																						
AOC 16 (MY5)	NO EXCEEDANCES																						
AOC 16 (MY6)	NO EXCEEDANCES																						
AOC 16 (MY7)	NO EXCEEDANCES																						
AOC 16 (MY2)	NO EXCEEDANCES																						
AOC 24	NO EXCEEDANCES																						
SWMU 11B	NO EXCEEDANCES																						
SWMU 13	NO EXCEEDANCES																						
SWMU 14	NO EXCEEDANCES																						
SWMU 52	NO EXCEEDANCES																						
AOC 16 (CY2)	NO EXCEEDANCES																						
AOC 16 (CY5)	NO EXCEEDANCES																						
AOC 16 (CY6)	NO EXCEEDANCES																						
AOC 22	NO EXCEEDANCES																						
SWMU 9	NO EXCEEDANCES																						
SWMU 25	NO EXCEEDANCES																						

Commented [s1]: Candace, Please insert revised table.

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Table 6-3. Constituents Detected at SWMUs and AOCs

SWMU/ AOC	VOCs				SVOCs				TEL/TOL			Lead			Arsenic			Iron			Other Metals		
	Surface Soils	Subsurface Soils	Impact to Groundwater (Unsaturated Soils)	Native Soils	Surface Soils	Subsurface Soils	Impact to Groundwater (Unsaturated Soils)	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils	Surface Soils	Subsurface Soils	Native Soils
AOC 16 (EY6)	NO EXCEEDANCES																						
AOC 16 (EY5)	NO EXCEEDANCES																						
SWMA 3	UNDERGOING CLOSURE (see SWMU 43 above)																						
SWMU 1	UNDERGOING CLOSURE																						
SWMU 2	UNDERGOING CLOSURE																						
SWMU 31	NFA PER HWSA PERMIT																						
SWMU 51	NFA PER HWSA PERMIT																						
SWMU 3	UNDERGOING CLOSURE																						
SWMU 32	NFA PER HWSA PERMIT																						
SWMU 45	NFA PER HWSA PERMIT																						

Central Yard
North Field/Main Yard
East Yard

SWMU 43 LNAPL Area
SWMA 1 RFI Area
SWMA 3 No Further Action Required

√ Applicable Residential Criteria Exceeded
√ Applicable Industrial Criteria Exceeded
√ Applicable Impact to Groundwater Criteria Exceeded

nc = Analyte detected in 1st round of sampling, but not confirmed in 2nd round.

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As shown on Table 6-2, tThe Facility-related chemicals that have been detected above the most conservative applicable soil delineation criteria in soil samples collected from the North Field/Main Yard include:

- **Seven Eight VOCs:** benzene, benzenethiol, cyclohexane, ethylbenzene, isopropyl benzene, toluene, 1,2,4-trimethylbenzene and ethylbenzene, xylenes. , benzenethiol, 1,2,4-trimethylbenzene and cyclohexane. Cyclohexane exceeded delineation criteria in only three four samples, and isopropylbenzene and 1,2,4-trimethylbenzene exceeded soil delineation criteria in only one sample.
- **Thirteen Eleven SVOCs:** quinoline, chrysene,benzo(a)pyrene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, carbazole, chrysene, dibenzo(a,h)anthracene, 2,4-dimethylphenol, indeno(1,2,3-cd)pyrene, naphthalene and quinoline.
- **Ten Metals and TOL/TEL**: aluminum, , antimony, , arsenic, , copper, iron, lead, mercury, nickel, vanadium and zinc. Zinc exceeded the soil delineation criteria criterion in only two samples, and mercury exceeded the soil delineation criterion in only one sample.

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A detailed analysis of the datadetailed review of every sample collected in the North Field/Main Yard indicates that just two organic compounds (benzene and benzo(a)pyrene) can be used to effectively represent areas where organic COCs are present above delineation criteria. These two constituents are also a reliable indicators

for total VOC compounds (TVOCs) and total organic compounds (TOCs). Of the ~~343~~ 370 soil samples that were analyzed for VOCs and/or SVOCs, ~~less tha~~only 2.1~~n 5~~% of the samples (e.g., seven samples) contained organic compound(s) that exceeded the most conservative residential delineation criteria but did not contain either benzene or benzo(a)pyrene above their respective delineation criteria. Of these seven samples, only one of the samples contained a compound (benzo(a)anthracene) that exceeded the industrial delineation ~~criteria~~criterion. Either benzene and/or benzo(a)pyrene was present above the delineation criteria in all but one of the samples from the North Field/Main Yard that contained TVOCs (including TICs) greater than 1,000 mg/kg or TOCs (including TICs) greater than 10,000 mg/kg. ~~Likewise,~~For TEL burial sites, the presence of lead and/or TOL appears to be a reliable indicator of the presence or absence of TOL.

In addition to arsenic, naturally~~-~~occurring iron and lead, ~~and~~ seven other metals (aluminum, antimony, copper, mercury, nickel, vanadium and zinc) have been detected above the most conservative delineation criteria in a small number of soil samples (e.g., ~~less than 10~~5% or less of the samples) from the North Field/Main Yard. Mercury (29 mg/kg) was detected in only one soil sample collected during the Phase II OWSS, and is not believed to be a site-related constituent, given that it was detected above soil delineation criteria in only one out of 345 soil samples. Aluminum, copper, mercury, nickel, vanadium and zinc were only detected above soil delineation criteria in samples that either contained catalyst beads and/or evidence of petroleum impacts. Aluminum, a~~A~~ntimony, mercury, nickel and vanadium were~~was~~ detected above the residential direct contact soil delineation criteria, but below applicable nonresidential direct contact criteria. ~~in ten soil samples, but was not detected above the industrial delineation criteria in any of the soil samples. In all~~Seven of ~~but three cases~~ the 10 samples that contained antimony above the applicable criterion~~,~~ also ~~it was detected in samples which~~ contained catalyst beads, foundry sand and/or evidence of petroleum impacts.

Elevated concentrations of arsenic (e.g., greater than the delineation criteria of 20 mg/kg) were found in approximately 13% of the samples. Arsenic appears to be more randomly distributed, as discussed previously. Although arsenic has been detected in many of the soil samples from the Refinery, concentrations of arsenic are usually less than 20 mg/kg. As discussed previously, these higher concentrations (e.g., greater than 20 mg/kg) may represent background concentrations as well since elevated arsenic soil concentrations have been found to be naturally occurring in New Jersey (e.g., glauconite-rich clay) (Sanders, 2003). The maximum concentration of arsenic in the North Field/Main Yard was 117 mg/kg.

6.3.3 Central Yard

In general, the Central Yard appears to be less impacted by Refinery-related activities than the North Field/Main Yard and East Yard. One LNAPL area is located just south of Maurer Road, and stained soils have been found in the vicinity of SWMU 34. Overall, the data collected during the RFI and OWSS investigations suggest that contaminated areas in the Central Yard are more localized around specific site-related activities.

Approximately 25% of the soil samples (205 samples) have been collected in the Central Yard. Of these, 52 soil samples were collected during the 1st-Phase Soils Investigation, 46 soil samples were collected during the OWSS investigations, and 107 samples were collected during the full RFI. Most of the samples (approximately 156 samples) were collected within the fill layer, about 32 of which were surface soil samples (zero to two feet bgs). Approximately 50 samples were collected from the underlying native material.

Most of the samples (156 samples) were analyzed for Skinner's List VOCs, TCL VOCs and/or BTEX. Approximately 177 samples were analyzed for SVOCs (either Skinner's List or TCL SVOCs) and/or PAHs. Approximately 82 samples were analyzed for metals, an additional 81 samples were analyzed for lead, and 82 samples were analyzed for TEL/TOL. The exceedances in each sample are shown on the summary tables that have been prepared for each SWMU and AOC (see Appendix A.3).

As summarized on Table 6-2, c~~C~~onstituents that have been detected above the most conservative soil delineation criteria in soil samples collected from the Central Yard include:

- **Three VOCs**: benzene, ~~xylenes and~~ benzenethiol and xylenes. ~~Xylene and~~B ~~b~~enzenethiol delineation ~~criteria~~ criterion ~~were~~ was only exceeded in one sample, and xylenes were detected in only two samples above the applicable delineation criterion.~~le.~~
- **Nine SVOCs**: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, carbazole, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, 2,4-dimethylphenol and ~~2-methyl phenol and~~ phenol.
- ~~Six~~ **Nine Metals and TOL/TEL**: a~~a~~ntimony, arsenic, barium, beryllium, iron, lead manganese, ~~and~~ nickel and zinc. Barium, beryllium,~~Antimony, barium~~ manganese, ~~and~~ nickel and zinc exceeded delineation criteria in one sample collected from SWMU 34. ~~A~~Arsenic and antimony were~~was~~ only detected above delineation criteria at SWMU 34.

Approximately 98.4% of samples which contained organic COC exceedances also contained either benzene and/or benzo(a)pyrene. Therefore, ~~Benzene and benzo(a)pyrene t~~these two compounds can be used to effectively represent areas where organic COCs are present above delineation criteria in most of the SWMUs and AOCs in the Central Yard, with the possible exception of AOC 30 and OWSS segment CY4. Benzo(a)anthracene (0.98J mg/kg) and TPH (16,000 mg/kg) were detected above the delineation criteria in one sample from AOC 30, but benzo(a)pyrene and benzene were detected below applicable criteria at this location. Likewise, one soil sample (SB0246SB) from OWSS segment CY4 contained phenol (67 mg/kg), 2,4-dimethylphenol (11 mg/kg) and/or benzenethiol (22 mg/kg) above the applicable delineation criteria, but did not contain benzene or benzo(a)pyrene above the delineation criteria.

Table 6-3 provides an overview of the types of constituents that were detected at each SWMU and AOC. ~~The SWMUs and AOCs are arranged according to whether they are identified LNAPL areas for which additional IRMs are planned, LNAPL areas that will be evaluated further in the CMS, confirmed TEL burial sites, etc.~~ A more detailed summary of the COCs that were detected in each Central Yard SWMU and AOC is provided in Table 6-5. This table shows whether the area is located near a property boundary, whether it is associated with an LNAPL area, whether there is evidence of petroleum-impacted soils, maximum concentrations of COCs that were detected above criteria in surface soils, subsurface soils, native soils and groundwater, an indication of whether surface water/sediments may have been impacted, and a recommendation as to whether the SWMU or AOC should be included in the CMS for further evaluation. If any COC was detected above applicable soil delineation criteria in any sample from a given SWMU/AOC, then the SWMU/AOC is recommended for further evaluation in the CMS. A complete discussion of each SWMU and AOC located in the Central Yard can be found in Appendix A.3.

Figures 6-~~17~~ 16 through 6-~~31~~ 30 show the distribution of samples analyzed for benzene, benzo(a)pyrene, lead, TOL/TEL and arsenic, as well as the relative concentration levels for each of these indicator COCs. These figures show the distribution of each of the indicator COCs in surface soils (zero to two feet bgs), in the intermediate layer (two to 10 feet bgs) and in deep soils (greater than 10 feet bgs). Delineation was completed by

using professional judgment, including delineation to a sample location where the indicator COCs were less than the applicable delineation criterion, using the edge of a physical barrier, such as a tank or tank basin (when appropriate), and using a decreasing concentration gradient to estimate the edge of the impacted area.

~~In general, the Central Yard appears to be less impacted by Refinery related activities than the North Field/Main Yard and East Yard. One LNAPL area is located just south of Maurer Road, and stained soils have been found in the vicinity of SWMU 34. Overall, the data collected during the RFI and OWSS investigations suggest that contaminated areas in the Central Yard are more localized around specific site related activities.~~

6.3.4 East Yard

Like the North Field/Main Yard, the East Yard has been used for petroleum-related activities since the late 1800's, and much of the East Yard has been filled with petroleum-impacted soils and other fill material. Seven LNAPL areas have been identified in the East Yard.

Approximately 27% of the soil samples (e.g., ~~228~~ 231 samples) were collected in the East Yard. Of these, ~~Approximately~~ 45 soil samples were collected during the 1st-Phase Soils Investigation, ~~24~~ 26 samples were collected during the OWSS investigations and 160 samples were collected during the first and second iterations of the Full RFI. Most of the samples (approximately ~~190~~ 192 samples) were collected within the fill layer. The remaining ~~38~~ 39 samples were collected in the native material underlying the fill layer. Approximately 57 of the fill samples were surface soil samples (zero to ~~2~~ two feet bgs).

Most of the samples (approximately ~~215~~ 218 samples) were analyzed for Skinner's List VOCs, TCL VOCs and/or BTEX. Approximately ~~185~~ 188 samples were analyzed for Skinner's List SVOCs, TCL SVOCs and/or PAHs. Approximately 204 samples were analyzed for metals and/or lead, and 80 samples were analyzed for TEL/TOL. Any exceedances of the respective delineation criteria for each sample are shown on the summary tables that have been prepared for each SWMU and AOC (see Appendix A.4).

The Facility-related chemicals that have been detected above the most conservative soil delineation criteria in soil samples collected from the East Yard include:

- ~~**Nine**~~ **Eight VOCs**: b~~b~~enzene, benzenethiol, cyclohexane, ethylbenzene, hexane[9], isopropylbenzene, toluene and ~~ethylbenzene,~~ xylene~~s, acetone, benzenethiol, chloroform, cyclohexane and hexane~~[10]~~.~~. ~~Chloroform, cyclohexane and~~ Ethylbenzene, hexane, isopropyl-benzene and toluene were only exceeded in one sample each.

[9]Hexane is a TIC that was detected in one sample (S0829D3) from SWMU 8. This sample also contained other VOCs above applicable criteria, including benzene (40 mg/kg).
[10] Hexane is a TIC that was detected in one sample (S0829D3) from SWMU 8. This sample also contained other VOCs above applicable criteria, including benzene (40 mg/kg).

- ~~Ten~~ Nine **SVOCs**: benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenzo(a,h)anthracene, indeno(1,2,3-cd)pyrene, pyrene, bis(2-ethylhexyl)phthalate and naphthalene ~~and 2,4-dimethylphenol~~. Pyrene and ~~2,4-dimethylphenol~~naphthalene were only exceeded in one sample.
- **Seven Metals and TOL/TEL**: a~~a~~ntimony, arsenic, copper, iron, lead, manganese and nickel. Manganese and nickel were only exceeded in one sample.

A detailed ~~analysis of the data~~review of every sample collected in the East Yard shows that approximately 99% of the samples with exceedances of organic COCs also contain benzene and/or benzo(a)pyrene. Therefore, ~~indicate that just~~these two organic compounds can be used to effectively represent areas where organic COCs are present above delineation criteria. These two constituents are also reliable indicators for TVOCs and TOCs. Either benzene and/or benzo(a)pyrene was present above the delineation criteria in all samples from the East Yard that contained TVOCs (including TICs) greater than 1,000 mg/kg or TOCs (including TICs) greater than 10,000 mg/kg. Likewise, the presence of lead and/or TOL appears to be a reliable indicator of the presence or absence of TOL. Elevated concentrations of arsenic (e.g., greater than the delineation criteria of 20 mg/kg) appear to be more randomly distributed, as discussed below.

Table 6-3 provides an overview of the types of constituents that were detected at each SWMU and AOC. ~~The SWMUs and AOCs are arranged according to whether they are identified LNAPL areas for which additional IRMs are planned, LNAPL areas that will be evaluated further in the CMS, confirmed TEL burial sites, etc.~~ A more detailed summary of the COCs that were detected in each East Yard SWMU and AOC is provided in Table 6-6. This table shows whether the area is located near a property boundary, whether it is associated with an LNAPL area, whether there is evidence of petroleum-impacted soils, maximum concentrations of COCs that were detected above criteria in surface soils, subsurface soils, native soils and groundwater, an indication of whether surface water/sediments may have been impacted, and a recommendation as to whether the SWMU or AOC should be included in the CMS for further evaluation. If any COC was detected above applicable soil delineation criteria in any sample from a given SWMU/AOC, then the SWMU/AOC is recommended for further evaluation in the CMS. A complete discussion of each SWMU and AOC located in the East Yard can be found in Appendix A.4.

Figures 6-~~32~~ 31 through 6-~~46~~ 45 show the distribution of samples analyzed for benzene, benzo(a)pyrene, lead, TOL/TEL and arsenic, as well as the relative concentration levels for each of these indicator COCs. These figures show the distribution of each of the indicator COCs in surface soils (zero to ~~2~~ two feet bgs), in the intermediate layer (~~2~~ two to 10 feet bgs, and in deep soils (greater than 10 feet bgs). Delineation was completed by using professional judgment, including delineation to a sample location where the indicator COC was less than the applicable delineation criterion, using the edge of a physical barrier, such as a tank or tank basin (when appropriate), and/or using a decreasing concentration gradient to estimate the edge of the impacted area.

~~Like the North Field/Main Yard, the East Yard has been used for petroleum related activities since the late 1800's, and much of the East Yard has been filled with petroleum-impacted soils and other fill material.~~

Although arsenic has been detected in many of the soil samples from the Refinery, concentrations of arsenic are usually less than 20 mg/kg, which is generally considered to be background in New Jersey soils as represented by the NJDEP soil cleanup criteria for both residential and industrial land use (Sanders, 2003). However, soil samples collected in the East Yard contained arsenic concentrations as high as 83 mg/kg. It should be noted that this portion of the Refinery borders the American Smelting and Refining Company, and elevated metals in this area may be attributable to windblown dust from the adjacent property. Alternatively, these higher concentrations may represent background concentrations as well, since elevated arsenic soil concentrations have been found to be naturally occurring in New Jersey (e.g., glauconite-rich clay) (Sanders, 2003).

6.4 Properties of Indicator COCs

This subsection provides an overview of the physicochemical properties of representative chemicals from the list of Facility-related chemicals that relate to mobility and persistence.

~~### 6.4.1 Contaminant Categories~~

Based on existing data, the three main types of chemicals present at the Refinery are VOCs, SVOCs and metals. To illustrate the typical physicochemical properties of these categories, representative chemicals were selected for further discussion based on their concentration, frequency of occurrence, migration potential, toxicity and carcinogenic potential. Benzene was selected to represent the VOCs, because it was regularly detected in the subsurface soil and groundwater samples. The PAH, benzo(a)pyrene, was selected to represent the SVOCs, because it was one of the most commonly detected SVOCs and is considered to be carcinogenic. Lead, TEL and arsenic were selected to represent the metals, because they are present in many areas of the Refinery at concentrations greater than their delineation criteria. Because organic compounds and metals behave differently in the environment, they are discussed separately.

LNAPL is included in this discussion because it has been encountered within many areas. Discussions of the fate of individual organic chemicals in the environment typically assume that these chemicals are not present as a separate organic phase. However, the presence of LNAPL at the Refinery may have implications for the mobility and persistence of individual chemicals. For example, low-solubility hydrophobic organic chemicals may migrate with LNAPL, or LNAPL may limit the potential for biodegradation. Thus, the characteristics of LNAPL are also presented, and they add another dimension to the discussion on the mobility of the organic compounds.

The mobility and persistence of chemicals in the environment are the two key characteristics in determining their probable behavior within the environment. Mobility is the measure of a chemical's propensity for transport. Persistence is the measure of how long a chemical will remain in the environment. Physicochemical and environmental factors that affect the behavior of a chemical include temperature, pH, concentration of other ions in the medium, soil moisture, oxidation-reduction (redox) potential (Eh), water chemistry, organic matter content and presence of macro- and microorganisms.

6.4.~~2~~1 Organic Compounds

Various physicochemical properties affect the transport of organic compounds in the environment. Eight important properties are described briefly below:

- The mobility of a chemical species in groundwater is controlled largely by water solubility. Water solubility is the maximum mass of a compound that can dissolve in a specific volume of water at a specific pH and temperature.

Highly soluble compounds tend to be more mobile in groundwater, tend to leach from the soils, and are generally more biodegradable. Less soluble compounds are more likely to adsorb to soil or sediment.

- The octanol-water partitioning coefficient (K_{ow}) is a function of a compound's water solubility and the capacity of the compound to adsorb to organic material. The K_{ow} is calculated experimentally by measuring the distribution of an organic chemical between octanol and water in contact with each other at equilibrium conditions. A compound with a high K_{ow} is hydrophobic and tends to remain sorbed on soils longer. Thus, the mobility of a compound with a high K_{ow} is retarded by its tendency to remain sorbed to soils. A compound with a high K_{ow} also tends to bioaccumulate in the lipid tissues of animals. A compound with a low K_{ow} tends to dissolve more in the aqueous phase, does not have the propensity to bioaccumulate, and is considered mobile in groundwater.
- The organic carbon partitioning coefficient (K_{oc}) is indicative of a compound's water solubility and the sorptive capacity of the organic compound onto organic material. The K_{oc} represents the ratio of the amount of chemical adsorbed per unit weight of organic carbon in the soil or sediment to the concentration of the chemical in solution at equilibrium. A compound with a K_{oc} of less than 75 has a very high mobility, while a compound with a K_{oc} greater than 500 has a low mobility.
- Vapor pressure is a relative measure of the volatility of a compound in its pure state. Compounds with high vapor pressures readily volatilize from the liquid form.
- The molecular weight of a pure compound influences the other physical characteristics of a compound. For example, organic compounds with higher molecular weights have less of a tendency to volatilize than those with lower molecular weights.
- The transport of non-aqueous phase liquids is affected by their specific gravity and water solubility. The density of a relatively insoluble compound present as a separate phase will determine whether it will sink or float in the saturated zone.
- Henry's law constant describes the distribution of a chemical between air and water at equilibrium. It is usually defined as the ratio of the spatial pressure of the compound in air, measured in atmospheres, to the mole fraction of the compound in a water solution. A high Henry's law constant indicates a tendency for a compound to volatilize from aqueous solution. For example, VOCs with a high Henry's law constant tend to transfer to the air in an air stripper.
- Biodegradation is the biological decomposition or chemical alteration of organic compounds by microorganisms. Many chemical constituents found in petroleum have been shown to be susceptible to biodegradation. Abiotic

degradation processes such as photolysis can also decompose organic compounds.

Dissolved oxygen is the most thermodynamically favored electron acceptor for the biodegradation of fuel hydrocarbons. Dissolved oxygen concentrations are used to estimate the mass of contaminant that can be biodegraded by aerobic processes. Each milligram per liter (mg/L) of dissolved oxygen consumed by microbes will destroy about 0.32 mg/L of BTEX compounds. During aerobic biodegradation, dissolved oxygen levels decrease as aerobic respiration proceeds. Dissolved oxygen concentrations less than 1 mg/L generally indicate that the conditions have shifted from an aerobic environment to an anaerobic environment (Weidemeir et al., 1994).

The redox potential of groundwater is a measure of electron activity and is an indicator of the relative tendency of a solution to accept or transfer electrons. Redox reactions in groundwater are often biologically mediated and therefore, the redox potential of a groundwater system depends upon and influences rates of biodegradation. The redox potential of groundwater generally ranges from -400 millivolts (mV) to 800 mV (Weidemeir, et al., 1994). As biodegradation proceeds, the redox potential of the groundwater decreases. The redox potential of a groundwater sample taken within a contaminant plume is typically less than that taken in an upgradient location. Thus, redox potential is an indicator of the extent and evolution of a groundwater contaminant plume as it proceeds downgradient through time.

The following chemical-specific profiles discuss how physicochemical properties and biodegradation affect the mobility and persistence of organic chemicals in the environment.

Light Non-Aqueous Phase Liquid

LNAPLs are a complex mixture of petroleum fractions that vary in composition, and typically contain hundreds of individual chemicals. Based on analytical fingerprinting, LNAPL encountered at the Refinery is typically composed of weathered crude, refining residuals, weathered diesel and weathered gasoline. Tank bottoms and sludges placed on the ground during past operations at the Refinery have also been encountered in soil borings.

LNAPL has been observed in monitoring wells and temporary piezometers as a layer of oil on water. The appearance of a floating LNAPL layer in a well appears to be caused primarily by the presence of the well, which represents a large void within the water bearing zone. The well allows otherwise discontinuous lenses or droplets of oil to collect and accumulate.

In an ideal setting, LNAPL resides in the capillary fringe zone above the water table, where the pore spaces of the soil are filled with water held in place by capillary attraction. Under conditions of a static or falling water table, LNAPL tends to accumulate in observation wells. However, LNAPL can become trapped below the water table as the water table rises. The net result is that under conditions of a rising water

table, minimal or no LNAPL will be observed in an observation well, even though LNAPL is present in the soils. Thus, water table fluctuations play an important role in the appearance of LNAPL in observation wells.

Weathering is the process by which the composition of LNAPL changes over time. Change occurs primarily from volatilization, degradation and leaching. Generally, the overall loss rate decreases exponentially with time, and the material left behind becomes richer in more viscous and persistent components. The resultant weathered mixture of petroleum compounds is more stable. Many low-solubility compounds that are present in LNAPL have little tendency to volatilize or solubilize at detectable concentrations.

Based upon fingerprint testing, much of the LNAPL at the Refinery appears to be highly weathered. Roughly half of the identified LNAPL areas at the Refinery contain gasoline and diesel components. However, since the Refinery stopped producing gasoline and diesel in 1983, the gasoline and diesel in the LNAPL has been extremely weathered, with a resultant loss of many of the more volatile compounds.

Volatile Organic Compounds

Benzene has been selected as the representative chemical for VOCs at the Refinery, because it was the VOC most commonly detected at a concentration greater than its action level. Benzene has the highest water solubility and volatility of the VOCs that are commonly detected at the Refinery. When released to soil, it volatilizes rapidly near the surface. The benzene that does not evaporate is highly mobile and will leach to groundwater. Under anaerobic groundwater conditions, benzene has a conservatively estimated half-life of ~~2~~ two years and will degrade more slowly than toluene or ethylbenzene. Benzene degrades more rapidly under aerobic conditions (half-life estimates of ~~5~~ five to 10 days). If released to surface water, benzene rapidly volatilizes, with half-life estimates of hours to a few days depending on surface water conditions such as depth, temperature, mixing within the water body and wind speed. Benzene will not bind appreciably to sediments. Photodegradation and biodegradation can also play a role in the removal of benzene from a surface water body; however, these processes are slower than volatilization. Based on its low estimated bioconcentration factor (BCF), benzene will not bioaccumulate.

Polycyclic Aromatic Hydrocarbons

PAHs are often present in LNAPL. PAHs are relatively persistent at the Refinery and represent a broad class of compounds ranging from low molecular weight components, such as naphthalene, to high molecular weight compounds like indeno(1,2,3)pyrene. Benzo(a)pyrene has been selected as the representative chemical for the SVOC contaminant category, because it is considered to be carcinogenic. The solubility, volatility, biodegradability and toxicity of PAHs vary widely. PAHs present in subsurface soils may be adsorbed to soil organic carbon or exist as an LNAPL component. The low molecular weight PAHs (e.g., naphthalene) have higher water

solubilities and are more likely to be released into groundwater than the higher molecular weight PAH compounds.
Photolysis and biodegradation are two common attenuation mechanisms for PAHs. Although PAHs transform in the presence of light by photolysis, the transformation rates are highly variable between different PAHs. Photolysis may reduce concentrations of PAHs in surface water or surface soils, but is not relevant for subsurface soils. The rate of biodegradation of PAHs in soils is also extremely variable across the chemical class. Generally, the lower molecular weight PAHs biodegrade more readily than the higher molecular weight PAHs; however, site-specific biodegradation rates are difficult to estimate because of the many factors that affect the rate. These factors include the availability of electron receptors, types of microorganisms present, availability of nutrients, presence of oxygen and chemical concentration.

PAH degradation occurs more slowly in aquatic environments than in the atmosphere, and the cycling of PAHs in aquatic environments is poorly understood. In surface water, PAHs can evaporate, disperse into the water column, become incorporated into bottom sediments, concentrate in aquatic biota or experience chemical oxidation and biodegradation. The most important processes for the degradation of PAHs in aquatic systems are photooxidation, chemical oxidation and biological transformation by bacteria and animals. Most PAHs in aquatic environments are associated with particulate materials. PAHs dissolved in the water column degrade rapidly through photooxidation. PAHs degrade most rapidly at higher concentrations, elevated temperatures, elevated oxygen levels, and higher incidences of solar radiation. Animals and microorganisms can metabolize PAHs to products that undergo complete degradation. PAHs in soil may be assimilated by plants, degraded by soil microorganisms or accumulate to relatively high levels in the soils.

6.4.2 Metals

The environmental fate of metals differs from that of organic compounds in that metals may undergo chemical transformations, but they do not degrade. Transformations include changes in oxidation states, precipitation with anions, adsorption, combination with organic ligands or uptake by organisms. Some of these transformation processes may result in the immobilization of metals.

The fate and rate of migration of metals primarily are influenced by adsorption, precipitation and the formation of dissolved complexes with anions or organic compounds. Adsorption is the process whereby dissolved ions are removed from the aqueous phase by attaching to surface sites on solid particles. Positively charged metal cations are adsorbed to balance the negative surface charges on soil and organic matter particles. The cation exchange capacity of the soil, the presence and relative quantity of other cations and various other factors affect adsorption rates. Precipitation refers to geochemical reactions in which dissolved metals combine with anions such as hydroxide (OH^-), carbonate (CO_3^{2-}), and sulfate (SO_4^{2-}) to form solid precipitates. Both adsorption and precipitation are highly dependent on pH and redox potential. Thus, as the

biodegradation of a plume of organic compounds changes the pH and redox potential of groundwater, the relative mobility of a given metal may increase or decrease.

Arsenic

Many arsenic compounds tend to adsorb to soils or sediments, and leaching usually results in transportation through soil only over short distances. The transport and partitioning of arsenic in water depends upon its chemical form (oxidation state and complexation). Soluble forms move with the water, but arsenic may be absorbed from the water onto sediments or soils, especially clays, iron oxides, aluminum hydroxides, manganese compounds and organic material (Callahan et al., 1979; USEPA, 1982; Welch et al., 1988).

Arsenic in water can undergo a complex series of transformations, including oxidation-reduction reactions, ligand exchange, and biotransformation. The predominant forms of arsenic in groundwater are the oxyanions arsenate (AsO_4^{3-}) and arsenite AsO_3^{3-}) (Robertson, 1989; Welch et al., 1988). Under anaerobic conditions arsenate may be reduced to arsenite. Arsenate compounds are typically fixed to soil and thus are relatively immobile. Arsenite compounds are ~~4~~ four to 10 times more soluble than arsenate compounds.

Transformations of arsenic in soil are similar to those in aquatic systems, with As^{5+} predominating in aerobic soils; As^{3+} predominating in slightly reduced soils (e.g., temporarily flooded); and arsine, methylated arsenic and elemental arsenic predominating under strongly reducing, anaerobic conditions (e.g., swamps and landfills) (USEPA, 1982).

Lead

Migration of lead in groundwater is limited by the tendency of lead to form relatively insoluble compounds. Lead forms a variety of compounds with low solubilities under natural Eh-pH conditions, including $PbSO_4$ ($K_{sp} = 10^{-7.8}$), and $PbCO_3$ ($K_{sp} = 10^{-13.1}$) (Krauskopf, 1979). K_{sp} refers to the solubility product of the ion pair. If the concentration (moles per liter (mole/L)) of either or both ions exceeds the solubility product, then precipitation will occur. Lead can be expected to adsorb strongly to soils rich in clays and iron and manganese oxides. The mobility of lead is largely controlled by pH, and the dissolved fraction of lead tends to increase as pH decreases. Typically, only a small fraction of sorbed lead is leachable in groundwater with a natural pH of 6.5 to 8. Thus, the mobility of lead in groundwater is limited. In biomethylated tetramethyl forms, lead may volatilize to the atmosphere.

6.4.3 TEL/TOL

TEL is a man-made compound in which a carbon atom of an organic molecule is bound to a lead atom. TEL is a colorless, oily liquid with a musty odor, and is often dyed red, orange, or blue, depending upon its use (USEPA, 1999).

TEL that is released to the environment primarily exists in the gas phase; however, a small percentage may be absorbed onto atmospheric particulates. Gas phase TEL in the atmosphere degrades rapidly by direct photolysis and by reaction with photochemically generated hydroxyl radicals and ozone molecules. The half-life of TEL ranges from approximately two hours under summer conditions to several days in winter. The estimated half-lives are: photolytic degradation under bright sunlight, 2.3 hours; reaction with hydroxyl radicals, 5.2 to 36.4 hours; and reaction with ozone molecules, 18 hours. If TEL is released to soil, it will still significantly photo-degrade and evaporate on soil surfaces; however, adsorption to soil may limit volatilization. TEL is not a persistent environmental compound, in that it is degraded to other forms of lead in water and soil, eventually forming stable inorganic lead compounds (USEPA, 1999).

In soils, most lead is retained as stable solid phase compounds, precipitates or complexes with organic matter. These forms of lead are quite insoluble and are unlikely to leach into groundwater unless acidic conditions are present.

TEL is practically insoluble in water, but it is soluble in organic solvents, benzene, ethanol, diethyl ether, gasoline and petroleum ether. Lead may also be present in groundwater if it has formed soluble complexes with certain substances (e.g., soluble organic matter, high concentrations of chlorides or sulfates) (USEPA, 1999).

Although 1st Phase ~~I s~~Soil data ~~was~~ were reported as "TEL", the values are actually representative of the total concentration of five potential alkyl-lead compounds detected in each soil sample, because the LUFT method does not differentiate between separate alkyl-metals (such as TEL). The five alkyl-lead compounds consist of tetra-methyl lead (TML), trimethyl-ethyl lead (TMEL), dimethyl-ethyl lead (DMEL), methyl-triethyl lead (MTEL) and TEL. Of these, TEL and TML are the most common alkyl-lead compounds that have been used in the past. TEL and TML are considered to be more toxic than trialkylead or dialkyllead compounds (USEPA, 2000). The soil data collected during the full RFI are more appropriately reported as total organic lead (TOL).

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6.5 Summary

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The most commonly detected chemicals that were also detected above their respective delineation criteria in soils include benzene, PAHs (primarily benzo(a)pyrene), and metals (lead, TOL, arsenic, and iron).

The main sources of environmental impact at the Refinery are likely to be associated with:

- The historical practice of filling low areas with potentially impacted dredge spoils, fill and Refinery wastes (for example, demolition debris and tank bottom deposits) to facilitate Refinery expansion;

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- Residuals in waste management units such as OWSs, TEL burial sites, wastewater treatment system components and other units including the OWSS; and
- Accidental spills and leaks from operational units and pipelines.

The SWMUs and AOCs in the North Field/Main Yard are in close proximity to one another. Therefore, it is difficult to attribute groundwater contamination and in some cases soil contamination to individual SWMUs as sources. One reason is that similar wastes were managed in the SWMUs, so the areas of contamination are often not readily distinguishable by the distribution of contaminants within them. In addition, the North Field/Main Yard has been used for petroleum-related activities since the late 1800's, and much of this area has been filled with petroleum-impacted soils, catalyst beads, and other fill materials. Like the North Field/Main Yard, the East Yard has been used for petroleum-related activities since the late 1800's, and much of the East Yard has been filled with petroleum-impacted soils and other fill material.

In general, the Central Yard appears to be less impacted by Refinery-related activities than the North Field/Main Yard and East Yard. One LNAPL area is located just south of Maurer Road, and stained soils have been found in the vicinity of SWMU 34. Overall, the data collected during the RFI and OWSS investigations suggest that contaminated areas in the Central Yard are more localized around specific site-related activities.

In general, the vertical and horizontal delineation of exceedances of COCs on an area or site-wide basis has been achieved. The Facility-related chemicals impacts are generally contained within the fill layer. The native peat/clay layer, that underlies much of the Refinery, is not impacted, except for some areas heavily impacted by LNAPL, where potential petroleum impacts have been identified in the upper peat layer.

Although arsenic has been detected in many of the soil samples from the Refinery, approximately 85% of the samples contained concentrations of arsenic at concentrations less than that considered to be background in New Jersey soils, as represented by the NJDEP soil cleanup criteria for both residential and industrial land use and various New Jersey Soils (Sanders, 2003). In addition to naturally occurring background, anthropogenic off-site activities, e.g., smelting and refining, may account for some of the higher arsenic soil concentrations (the maximum arsenic soil concentration was 117 mg/kg). Alternatively, these higher concentrations may represent background concentrations as well since elevated arsenic soil concentrations have been found to be naturally occurring in New Jersey, e.g. marine clay, where total arsenic levels have been reported to range from 13 to 131 mg/kg (Sanders, 2003). Therefore, arsenic is not considered a Facility related-chemical.

Site-wide exceedances of soil delineation criteria associated with PAHs, particularly benzo(a)pyrene, while constituents of petroleum, are widespread and inconsistent with a pattern of spills and releases, i.e., not attributable to known waste management units, but more likely associated with the historical practice of filling low areas with potentially impacted dredge spoils, fill, and Refinery materials to facilitate Refinery expansion. In other areas, these exceedances are part of the LNAPL areas and are collocated with VOC

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exceedances, predominantly benzene, representing the lighter end of the petroleum distillate range.

TOL has been detected in soils at the confirmed TEL burial sites, and in many cases has degraded to inorganic lead. Based on the RFI data and consistent with the literature, most of the lead associated with TEL has been retained, likely as stable solid phase compounds, precipitates or complexes with organic matter. These forms of lead are quite insoluble and are unlikely to leach into groundwater unless acidic conditions are present.

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